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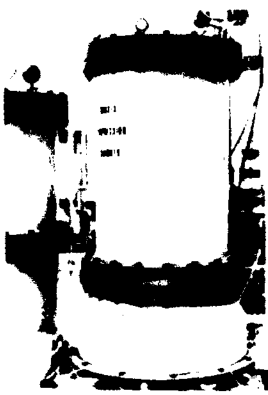

GEOTECHNICAL
LABORATORY

TECHNICAL REPORT GL-91-22

SEISMIC STABILITY EVALUATION OF RIRIE DAM AND RESERVOIR PROJECT

Report 1
CONSTRUCTION HISTORY AND FIELD AND LABORATORY STUDIES
Volume II: Appendixes A-J

2

by

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APPENDIX A: MODIFIED MERCALLI INTENSITY SCALE

(Housner 1970)

Intensity	Description
I	Detected only by sensitive instruments
II	Felt by a few persons at rest, especially on upper floors; delicate suspended objects may swing
III	Felt noticeably indoors, but not always recognized as a quake; standing autos rock slightly, vibration like passing truck
IV	Felt indoors by many, outdoors by a few; at night some awaken; dishes, windows, doors disturbed; motor cars rock noticeably
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects
VI	Felt by all; many are frightened and run outdoors; falling plaster and chimneys; damage small
VII	Everybody runs outdoors; damage to buildings varies, depending on quality of construction; noticed by drivers of autos
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken
X	Most masonry and frame structures destroyed; ground cracked; rails bent; landslides
XI	New structures remain standing; bridges destroyed; fissures in ground; pipes broken; landslides, rails bent
XII	Damage total; waves seen on ground surface; lines of sight and level distorted; objects thrown up into air

APPENDIX B: SUMMARY OF SAND AND FINE-GRAINED ALLUVIAL SOILS ENCOUNTERED IN EXPLORATION HOLES

Table B1

Instances of Alluvial Sand Encountered in Exploration Holes

Exploration Hole	Range in Depths, ft	Description
Drill hole DH-5	9 - 33 *	Gravelly sand and sandy gravel; loose to mod. compact, occ. cobbles
Drill hole D-10	25 - 34	Clayey, silty sand; occ. rock frags.
Drill hole D-12	10 - 22 *	Silty sand; occ. rock frags., wood chips and white shells
	30 - 45	Silty sand; black, occ. gravel, rock frags., and white shells
Drill hole D-14	38 - 44	Silty, clayey, gravelly sand; occ. rock frags.
	64 - 70	Silty sand; occ. rock frags.
Drill hole D-18	10 - 13	Silty, gravelly sand
	58 - 60	Sand; black
	81 - 85	Sand; black
Drill hole D-20	9 - 15	Gravelly, silty sand
Drill hole D-30	31 - 35 *	Gravelly sand
Drill hole D-32	6 - 11 *	Silty sand
	32 - 51	Silty, gravelly sand with cobbles
	51 - 57	Clayey, gravelly sand
Drill hole D-38	42 - 46	Clayey, silty, gravelly sand; rock frags.
Drill hole D-45	5 - 7	Silty sand
	23 - 28	Silty sand
	43 - 53	Silty sand; with rock frags.
	53 - 59	Gravelly, silty sand
Drill hole DH-46	7 - 16	Silty, gravelly sand; shell frags.
Drill hole DH-48	14 - 28	Silty, gravelly sand
Drill hole D-51	10 - 14 *	Silty, gravelly sand; with shells
Drill hole D-52	10 - 30	Gravelly sand
	30 - 35	Silty sand; v. occ. gravel

(Continued)

(Sheet 1 of 4)

Table B1 (Continued)

Exploration Hole	Range in Depths, ft	Description
Drill hole D-58	10 - 20	Silty sand; shells and cobbles
	30 - 40	Silty sand; occ. gravel
	40 - 45	Clayey sand; brecciated rock frags.
Drill hole DH-60	20 - 25	Silty sand
	25 - 31	Silty sand; rock frags. and gravel
Drill hole D-63	10 - 15 *	Gravelly sand; shells, occ. boulders
Drill hole DDH-70	24 - 26	Gravelly, silty sand
	39 - 40	Sand; coarse, black
	77 - 81 †	Silty sand (lab: SM); firm, brown
	90 - 91 †	Silty sand (lab: SM); hard, brown
Drill hole DDH-72	26 - 28	Gravelly sand
	61 - 63 †	Sand
	65 - 67 †	Sand
	82 - 84 †	Sand (lab: SP-SM)
	92 - 96 †	Sand and clay;brittle, layered, brown
	98 - 100 †	Silty sand
Drill hole DDH-73	26 - 29 *	Silty sand; with rock frags.
	29 - 37 *	Gravelly sand; coarse, black sand
	37 - 44 *	Gravelly sand; with rock frags.
	65 - 66 *	Silty sand
	66 - 71 *	Sand; soft, gray
	71 - 74 *	Silty sand (lab: SP-SM)
	74 - 79 *	Sand; fine, soft, water-deposited, saturated, brown
	81 - 86 *,††	Sand; soft, wet, brown
	86 - 92 *,††	Sand; very hard, cemented
Drill hole DDH-74	33 - 53	Sand; water deposited, rock frags, brown
Drill hole D-75	55 - 58 *	Sand; fine, dark brown
	58 - 62 *	Gravelly sand
Drill hole DDH-76	37 - 42 *	Sand; medium to fine, black
	42 - 60	Gravelly, silty sand; medium to fine, black
	72 - 91	Silty sand; medium to fine, black
Drill hole DDH-77	17 - 35	Gravelly, silty sand; angular, gray
	35 - 41	Sand
	41 - 53	Gravelly, silty sand; coarse, gray, increase in silt at 52'

(Continued)

(Sheet 2 of 4)

Table B1 (Continued)

Exploration Hole	Range in Depths, ft	Description
Drill hole D-78	27 - 36	Silty sand; gravel and rock frags.
Drill hole RD-83	0 - 28 *	Silty sand
Drill hole RD-84	13 - 19 *	Gravelly sand; with sea shells
Drill hole RD-95	9 - 11 *	Silty sand; fine
Drill hole RD-110	85 - 93 *,†	Sand; gray
Drill hole RD-112	118 - 120 †	Silt and sand
Drill hole DH-117	18 - 23	Silty sand; trace of clay
Drill hole CD-125	28 - 60	Gravelly sand
Drill hole CD-126	12 - 24 *	Gravelly sand
	29 - 42 *	Gravelly sand; with rock frags.
	48 - 50 *	Silty sand; fine, rock frags.
Drill hole CD-127	10 - 20 *	Gravelly sand
	35 - 36 *	Sand (possibly)
	42 - 50 *	Sand; possible clay layer
	60 - 65 *	Gravelly sand
	70 - 75 *	Gravelly sand
	75 - 76 *	Sand
Drill hole CD-135	17 - 25	Silty, gravelly sand
	50 - 62	Gravelly sand
	64 - 69	Gravelly sand
Drill hole CD-137	55 - 70	Silty, gravelly sand
	92 - 96 †	Sand; lens of silt; occ. rock frags.
	99 - 100 †	Sand
Drill hole CD-142	45 - 65	Heaving sand
Drill hole CD-143	18 - 55 *	Gravelly sand
Drill hole CRD-154	87 - 90	Sand with silt
Drill hole RD-171	94 - 97 †	Sand; fine, light brown
Drill hole CRD-174	27 - 47	Gravelly sand
	57 - 82	Gravelly sand
Drill hole CDH-187	30 - 32 *	Sand; medium, tan, basalt frags.
Drill hole CDH-190	32 - 34	Sand and small-sized gravel
Test pit, T-15	7.0 - 10.0 **	Gravelly sand; small sea shells
Test pit, T-16	7.0 - 8.0 **	Gravelly sand

(Continued)

(Sheet 3 of 4)

Table B1 (Concluded)

Exploration Hole	Range in Depths, ft	Description
Test pit, T-19	11.0 - 12.0 *	Sand, fine
	12.0 - 13.0 *	Gravelly sand; small-sized gravel
	22.0 - 23.0	Sand, compact
Test pit, T-20	9.0 - 10.0 *	Sand, fine

* These materials most likely were removed in the process of excavating the core trench (using Plate 49, US Army Engineer, 1977a).
** Lower depth corresponds to the bottom of the exploration.
† Estimated to be tuffaceous sediments.
†† Thought to be shear zone.

Table B2

Instances of Alluvial Clay and Silt

Encountered in Exploration Holes

Exploration Hole	Range in Depths, ft	Description
Drill hole DH-5	53 - 64	Silt clay; some gravel talus frags.
Drill hole D-10	90 - 116	Sandy clay; trace sand
Drill hole D-12	22 - 30 *	Sandy, clayey silt; occ. rock frags.
Drill hole DH-17	31 - 35	Silt, clay, rock frags, brown
Drill hole D-18	76 - 81	Silt, silty sandy rock frags., brown
Drill hole D-20	67 - 77	Clayey silt to clay
Drill hole D-27	42 - 47	Sandy gravelly silt
Drill hole D-38	17 - 27	Gravelly, sandy clay;with rock frags.
	40 - 42	Silty clay
Drill hole D-41	7 - 12	Sandy silt; with rock frags.
	12 - 27 *	Silty clay and rock frags.
Drill hole D-42	35 - 37	Sandy clay (lab: ML-CL)
	42 - 57	Sandy clay (lab: ML-CL); occ. rock frags., green & brown
Drill hole D-45	37 - 43	Sandy clay (lab: CL)
	58 - 64	Sandy silt; streaks of clay
	64 - 70	Sandy clay (lab: CL); with rock frags.
Drill hole DH-46	18 - 32	Sandy, gravelly clay
		Sandy silt; streaks of clay
	48 - 58	Silty clay; compact, plastic, brown
	75 - 78 **	Sandy, silty clay
Drill hole D-47	80 - 84	Gravelly, sandy silt (lab: MH)
Drill hole DH-48	28 - 51 **	Sandy clay; with rock frags.
Drill hole D-51	40 - 48	Sandy clay (lab: CL); occ. cobbles
	55 - 69 *	Red clay (lab: CH-CL); with gravel and rock frags.
Drill hole D-52	45 - 53	Silt & organic material; occ. gravel
Drill hole D-55	75 - 79	Silt; occ. gravel
Drill hole D-58	25 - 30	Clayey silt
	45 - 54	Sandy clay (lab: CL)

(Continued)

(Sheet 1 of 6)

Table B2 (Continued)

Exploration Hole	Range in Depths, ft	Description
Drill hole D-60	31 - 35	Clayey silt; occ. boulders
	40 - 44	Gravelly clay (lab: CL)
	44 - 50	Sandy, gravelly clay (lab: CL)
Drill hole DH-61	32 - 57 *	Silty clay; with rock frags.
Drill hole D-63	35 - 45 *	Sandy, gravelly clay (lab: CL)
Drill hole DH-65	5 - 58	Sandy, silty clay; with rock frags.
Drill hole D-66	44 - 50	Sandy silt
Drill hole DH-67	3 - 31 *	Sandy silt; with rock frags.
	31 - 69	Silty clay; with rock frags.
	69 - 72	Silty clay
	72 - 76	Silty clay; with rock frags.
	76 - 82	Silty clay; occ. streaks of gravel
	82 - 112	Clay; highly plastic
Drill hole DDH-70	26 - 27	Gravelly, sandy silt; with cobbles and rock frags.
	41 - 43	Sandy silt; brown and black
	43 - 48	Sandy, clayey silt; rock frags.
	56 - 57	Clay
	61 - 66 ††	Sandy clay (lab: CL); very hard, moist, brown, layers green clay
	66 - 68 ††	Silty clay (lab visual)
	68 - 71 ††	Clay (lab: CL); hard, moist, fissured, brown
	71 - 74 ††	Sandy clay (lab: CL); firm, moist, brown
	74 - 78 ††	Clay (lab: CL)
	81 - 83 ††	Clay (lab: CL); hard, moist, tan
	83 - 85 ††	Sandy silt (lab: ML); hard, moist
	85 - 86 ††	Sandy clay (lab: CL); very hard
	86 - 90 ††	Silt (lab: ML), hard, moist, some fine sand, brown
	91 - 96 ††	Sandy silt (lab: ML)
	99 - 100 **,††	Clayey silt (lab visual); firm

(Continued)

(Sheet 2 of 6)

Table B2 (Continued)

Exploration Hole	Range in Depths, ft	Description
Drill hole DDH-72	37 - 39	Gravelly, silty clay
	39 - 43	Clay (lab: CL); soft to firm, moist, trace of sand, light brown
	43 - 45	Clayey silt (lab visual)
	45 - 48	Clay (lab: CL); firm, moist, occ. rock frags., brown
	48 - 51	Silty Clay (lab visual)
	51 - 54	Clay; brown
	54 - 56	Silt (lab visual); firm, moist, tan
	56 - 58 †	Clay (lab: CL); firm, moist, brown
	58 - 60 †	Silty clay (lab visual); moist
	60 - 61 †	Clay (lab: CH); hard, moist, brown
	67 - 73 †	Clay (lab: CH); hard, brittle, moist light brown
	73 - 77 †	Silty clay (lab visual)
	77 - 79 †	Clay (lab: CH); occ. rock frags.
	79 - 82 †	Sandy silt (lab visual)
	84 - 89 †	Clay (lab visual); hard, brittle, rock frags., brown
	89 - 92 †	Silt (lab: ML); hard, brittle, moist, brown
	92 - 96 †	Silt and clay (lab visual); brittle, layered, brown
	96 - 98 †	Sandy silt (lab: MH); cemented
Drill hole DDH-73	55 - 58 *	Clayey silt; rust color
	58 - 59 *	Silty clay (lab visual)
	59 - 60 *	Clay (lab: CL); with rock frags.
	60 - 62 *	Silty clay (lab visual)
	62 - 64 *	Clay (lab: CL); fissured, brown
	79 - 81 *,†	Sandy clay
	92 - 100 *,**,††	Clay (lab: CL); hard, brittle, fissured, brown
Drill hole DDH-74	25 - 29	Sandy silt; clay streaks
	29 - 31	Clay (lab: CL); with rock frags.
	31 - 33	Sandy silt (lab visual)
Drill hole DDH-76	26 - 32 *	Sandy silt; occ. cobbles

(Continued)

(Sheet 3 of 6)

Table B2 (Continued)

Exploration Hole	Range in Depths, ft	Description
Drill hole DDH-77	59 - 93	Clay; lean, brownish red
Drill hole RD-78	21 - 27	Silt; soft, occ. rock frags.
Drill hole RD-79	41 - 54 *	Gravelly silt; light brown
	54 - 62 *	Clay; v. occ. gravel, reddish brown
	62 - 68 *	Silt; light brown
	68 - 69 *	Clay
Drill hole RD-84	40 - 55	Gravelly silt
	55 - 65	Clay (lab: CL); lt. reddish brown
	65 - 68	Silt (lab: ML); trace clay
	68 - 75	Clay (lab: CL)
Drill hole RD-95	29 - 36	Clayey silt; reddish brown
	36 - 40	Clayey silt; buff
Drill hole RD-96	27 - 29 *	Clayey silt
Drill hole RD-110	27 - 38 *	Clayey silt; with rock frags.
Drill hole CD-130	71 - 74 *	Silt
Drill hole CD-137	70 - 78 †	Clay; reddish brown sand
	78 - 80 †	Clay and siltstone
	80 - 81 †	Clay; with rock frags.
	85 - 87 †	Clay and siltstone
	87 - 90 †	Clay; reddish brown
	90 - 92 †	Clay; light green
	96 - 99 †	Clay; with rock frags.
Drill hole CD-139	78 - 81	Clay
	81 - 90	Clay; with rock frags.
	90 - 92 †	Clay; with siltstone
	92 - 93 †	Silt
	93 - 97 †	Clay; reddish brown
	97 - 110 **,†	Silt
Drill hole CD-143	73 - 75	Silt
Drill hole CRD-154	67 - 70	Clay
	70 - 73	Silt
	73 - 81	Clayey silt
	81 - 87	Silt; with siltstone
Drill hole CRD-175	55 - 71	Silt; with rock frags., brown

(Continued)

(Sheet 4 of 6)

Table B2 (Continued)

Exploration Hole	Range in Depths, ft	Description
Drill hole CRD-176	45 - 73	Sandy silt; brown
Drill hole CRD-177	45 - 61	Sandy silt
Drill hole CRD-178	42 - 53	Silt; brown
Probe hole PN-2	28 - 36	Sandy silt
Probe hole PN-3	25 - 35	Sandy silt
	35 - 40	Sandy (clayey) silt
Probe hole PN-4	30 - 36	Sandy, gravelly silt
Probe hole PN-5	61 - 65	Sandy, gravelly silt
Probe hole PN-6	41 - 44	Gravelly, sandy silt
Probe hole PN-7	50 - 59 **	Gravelly clay
Probe hole PN-8	62 - 70 **	Gravelly clay
Probe hole PN-9	53 - 67 **	Sandy, silty clay; with rock frags.
Probe hole PN-10	17 - 33	Sandy, gravelly silt
Probe hole PN-13	23 - 28	Sandy silt; with rock frags.
	40 - 53	Sandy silt; with rock frags.
Probe hole PN-14	20 - 31	Gravelly, sandy silt
Probe hole PN-22	53 - 66	Clay; with rock frags.
Probe hole PN-23	37 - 50	Clay; with rock frags.
Probe hole PN-24	60 - 71 **	Clay; with rock frags.
Probe hole PN-25	34 - 39	Gravelly silt
	58 - 63 **	Clay; with rock frags.
Probe hole PN-26	34 - 38	Gravelly silt
	58 - 62 **	Clay; with rock frags.
Probe hole PN-27	43 - 50	Gravelly, sandy silt
	57 - 62 **	Clay; with rock frags.
Probe hole PN-28	35 - 38	Gravelly, sandy silt
	58 - 63 **	Gravelly clay
Probe hole PN-29	38 - 45	Gravelly, sandy silt
Probe hole PN-31	58 - 64 **	Clay; with rock frags.
Probe hole PN-35	20 - 28	Sandy silt

(Continued)

Table B2 (Concluded)

Exploration Hole	Range in Depths, ft	Description
Probe hole PN-36	11 - 38	Silt clay and rock frags., incl. boulder sizes
Test pit T-18	10 - 19	Sandy silt; with rock frags., incl. boulder sizes
	19 - 25	Silt; dark gray to rust
	26 - 28 **	Silt; with rock frags.
Test pit T-20	59 - 60	Sandy silt

* These materials most likely were removed in the process of excavating the core trench (using Plate 49, US Army Engineer, 1977a).
** Lower depth corresponds to the bottom of the exploration.
† Estimated to be tuffaceous sediments.
†† Thought to be shear zone.

APPENDIX C: ROCK FILL TEST PROGRAM

(Taken in its entirety from US Army Engineers 1978)

RIRIE TEST FILLS - 21, 22 and 23 May 1974

BACKGROUND INFORMATION - The rock excavation at Ririe Dam has become a major problem in that the material is so variable the Contractor cannot meet our specification requirements without excessive processing. Colonel Conover has requested that we study the problem and attempt to reach a solution which will permit use of the material with less processing, thus helping the Government as well as the Contractor. It has been orally agreed with the contractor that if the requirements of the specifications can be reduced to where the material may be used with a minimum of processing, the Contractor will not push his claim for a changed condition in the spillway. With this in mind, a meeting was held with the Contractor's representatives at the project office on 7, 8 and 9 May 1974. At this meeting it was propsed that granular fill be permitted both upstream and downstream of the core and filters below Elev. 5050. The granular fill would consist of 12-in. minus material obtained from basalt rock excavation and containing no more than 12 percent, by weight, passing the No. 200 sieve. Rock fill, as specified, would still be required above Elev. 5050, but it would consist primarily of 12-in. plus material. In later discussions with Mr. M. W. Anderson of NPD [North Pacific Division, Portland], he expressed the opinion that it would be better to separate material on a somewhat smaller screen or grizzly such as an 8 or 10-in. This proposal, as presented to the Contractor, would require passing a substantial portion of the excavated material over a grizzly but would result in an excellent fill. The Contractor's proposal, as presented by Mr. Westerman, was to pass the material over three screens -- a 6-in., 3-in., and 1/2-in. (or 5/8, 3/4, or 1-in. as necessary due to "balling up" of the clayey fraction) and then use the smaller fraction in the random fill section and blend the other sizes back together for Type I rock fill. The Corps representatives felt that the Contractor could never meet the required production with this plan and the the processing would be very costly. The Contractor agreed to consider the granular fill idea as presented to them and let the Corps know what they decided. Evidently, they have kept in close contact with Colonel Conover and Bert Hoare relative to their plan of operations.

During the week of 13 May, Messrs. Gullixson, Hulce, Shepherd and K. Jones were at the project with the Resident Engineer to investigate the Contractor's claim of a changed condition in the spillway excavation. Colonel Conover and Mr. Cuckler were also present during this time and arranged

another meeting with the Contractor. At this meeting, the Contractor volunteered to construct test fills using pit-run rock fill and also using an 18-in. rock rake to rake larger stone to the outside of the zone. Test fills were scheduled to be constructed beginning toe moring of 21 May 1974. Mr. M. W. Anderson from NPD and R. T. Mork from NPW would be present to observe and direct the work. The Contractor suggested more than one test fill and said an 18-in. rock rake would be available for use during the tests.

PURPOSE - The purpose of the test fills was to provide information on the characteristics of the materials available from the spillway excavation to attempt to permit revising the specifications to better use the available material and to reduce the amount of processing required prior to placement.

MATERIALS SOURCES - The materials used in the test fills consisted of intra-canyon basalt from required excavation of the spillway. Three areas of excavation were available for use. They were: (1) an area between Stations 53+45 to 54+25, Elev 5145 to 5165 and 125 ft left of spillway centerline to 20 ft right of the spillway centerline; (2) an area between Stations 43+00 to 44+00, Elev. 5115± and 20 ft left of the spillway centerline; and (3) an area near Station 47+00, Elev. 5090±, about 30 ft left of spillway centerline and consisting of first flow basalt rather than intra-canyon basalt.

LOCATION OF TEST FILLS - Test Fill No. 1 was constructed on an area between spillway centerline Stations 59+50 and 60+10, extending from 280 ft left of the spillway centerline to 400 ft left of the centerline at approximate Elev. 5150. Test Fill No. 2 was constructed at approximate Station 43+20 alongside the source of the material used. The size of this test fill was approximately 70 by 40 ft at Elev. 5115± and it was positioned very near the spillway centerline.

CONSTRUCTION OF TEST FILLS - After walking over the materials source between Stations 53+45 to 54+25 and discussing the equipment available, it was decided to place the first lift of Test Fill No. 1 in a three-foot lift, spread with a D-8 dozer and compact with two passes of a 20-ton vibratory roller. No rock rake was to be used because the only rake available was a brush rake with teeth approximately 12-in. long and spaced at 12 in. on center. It was felt that this rake would be most ineffective in moving larger rock to the outside of the fill as the teeth were not long enough and were too close together. In a 3-ft lift, such a rake would, in effect, just remove rock from the upper 12 in. of the lift and the end result would be two feet of rock fill covered

with a foot of minus 12-in. granular material. Compaction of such a laminated fill would be difficult and such a fill is undesirable in that the material is too variable. It was felt that better compaction and a better end product should result from just placing directly into a 3-ft lift and spreading as it would be normally done during embankment construction. The first few loads of material placed in the test fill consisted of clean, large rock. As the source is dozed and worked for the front end loader's operation, segreagation occurs and the first few loads consist of the larger rock from the toe of the slope. The dirtier rock fill was placed through the middle of the lift and then, because of repositioning of the front end loader, the last portion of the lift was again clean, coarse rock fill. The first lift was 60 ft wide by 120 ft long. Two end dumps were hauling material and a D-8 dozer was doing the spreading. Since material was delivered to the fill rather slowly, the dozer accomplished a lot of extra compaction - much more than a normally-placed embankment would receive.

Upon completion of the first lift, the surface of the lift was profiled and elevations determined at points on a 20-ft grid both ways. Then the lift was compacted with two passes of a 20-ton vibratory roller (Raygo Rascal 500A) and the surface was againg profiled and eleveations determined at approximately the same points on a 20-foot grid both ways. The quality control people placed a row of laths down the south side of the fill spaced at 20-ft intervals and the rodman chained from each lath to the point, visually positioning himself normal to the row of laths.

Prior to beginning the seconed lift, a marker layer of rhyolite was placed on the fill so lifts could easily be identified later on during excavation. The marker zone was to be about two-inches thick, but ended up considerably thicker. The second lift was then constructed similarly to the first lift. The material in this lift appeared to contain more small material and less coarse rock. As before, there were some loads of relartively clean rock and others of much dirtier rock. For the entire lift, however, there appeared to be less coarse material and more of the smaller material. The second lift surface was about 50 ft by 80 ft in size and the surface was profiled, compacted, re-profiled and marked with a thin zone of rhyolite material just as lift number one was prior to the start of the third lift.

When the second lift was completed, it was decided to use material from another source for the third lift. The Contractor suggested a source from the

first basalt flow near Station 47+00 and from Elev. 5090±. The material in the area examined appeared to be finer and more typical than some zones. Upon delivery to the test fills, however, the material looked very similar to the other two lifts. It varied from clean, coarse rock fill to dirty rock fill with a high percentage of fines. The top of the third lift was about 40 ft by 70 ft and it was profiled, compacted and re-profiled just like the first two lifts.

During placement in all three lifts of Test Fill No. 1, the material appeared to spread very well and compaction did not really work the fill as much as had been expected. Profiling indicated a settlement of only 0.1 to 0.2 ft resulted from rolling the lifts with the 20-ton vibratory compactor. However, the lifts had received considerably more than a normal amount of dozer compaction as previously stated.

Test Fill No. 2 was built during the second and third lifts of Test Fill No. 1. Material was moved from the shot rock pile into the first lift with a 966 front end loader. Before any spreading was done, material for the entire lift was dumped in piles. Because of the nature of the material (generally smaller in size), the lift was spread to a two-foot thickness. The surface of each lift was treated exactly the same as those in Test Fill No. 1.

Lift number two was also placed in a two-foot thick lift, but was placed as it would be in an embankment. That is, two or three front end loader loads would be dumped and then the D-8 would spread the material to the specified thickness. The 20-ton vibratory roller was brought in to compact each lift as in Test Fill No. 1. Lift number three was placed in a three-foot thick lift because the material appeared to be a little larger and also because it offered a comparison between a 2-ft and a 3-ft lift thickness. Placement and compaction of Test Fill No. 2 was very similar to that used in Test Fill No. 1 and the material appeared to react about the same. Profiles before and after rolling with the vibratory roller indicated about the same amounts of settlement and the fill reacted about the same during rolling. The size of the fill was considerably smaller than Test Fill No. 1 ending up about 30 ft by 50 ft on top of the third lift and about 50 ft by 70 ft at the bottom of the test fill.

PHOTOGRAPHIC COVERAGE - During the test fill construction, the project office took black and white photographs with a 4 by 5 speed graphic and colored

photos with a 35 mm camera. Messrs. Anderson and Mork also took personal pictures which are available for reference.

SAMPLING OF TEST FILLS - Upon completion of Test Fill Nos. 1 and 2, samples of the fill materials were obtained. In Test Fill No. 2, a trench was cut nearly through the fill using a 955A front-end loader. The top lift was sampled by loading out a truckload sample. Then the lowere two lifts were sampled as a composite as the material was similar. Each truckload sample was hauled to the town of Ririe to get the total weight. After weighing, the sample was dumped onto a concrete pad near the screening plant so it would not become contaminated with other material. Another front-end loader was then used to run the sample through the plant. The Contractor just has tow concrete pads for samples and can leave one in the truck overnight, so has facilities for thre samples. A close inspection of the sidewalls of the cut trenches in Test FIll No. 2 indicated very little point-to-point contact of the rock fragments. The material in all three lifts was very dirty without evidence of very much rock. Most of the good rock was on the slopes of the test fill, it appeared, but there was actually a good distribution of rock fragments throughout the fill.

In Test Fill No. 1, each lift was sampled. A trench was dozed across the test fill just one lift deep and after cleaning the sidewalls of the trench, a truckload sample was obtained from that lift. Then the dozer mover back in and dozed a trench through the second lift. Halfway through the fill, the dozer pulled out and the front-end loader sampled the middle lift. The bottom lift was sampled in a similar manner after the marker zone rhyolite was dozed off separately, since it was quite thick.

The cut slopes of the sampled area in Test Fill No. 1 were quite similar to Test Fill No. 2, except that there seemed to be more contact between the rock. Actually, the sampling was done through the dirtier portion of the fill, so it is certain that some parts of the fill would have had good point-to-point contact of the rock. The material was highly variable in size as it was placed, so it is also certain that some areas would have little, if any, point-to-point contact between the rock particles.

TESTING OF SAMPLES - Each sample was taken to the Town of Ririe to obtain its total weight. It was then dumped on a concrete pad and a front-end loader put it through the screening plant. A complete series of screens was used. The

6-in. to 1/2-in., the 1/2-in. to No. 4, and minus No. 4 materials were sampled using smaller samples, and results were then expanded to cover the entire sample. Of the five samples, the material passing the 6-in. screen contained an average of approximately 50 percent by weight passing the 1/2-in. screen using this method of sampling. The minus No. 4 material was wash-screened to determine the gradation of that material for each of the five samples. The percent by weight of the 6-inch minus passing the No. 200 sieve ranged from 6.8 to 18.1 and averaged 12.4 percent. This was probably somewhat dirtier than the average, as the samples were intentionally taken in the dirtier portions of the fils.

TEST RESULTS - Tabulations of the samples tested are shown on pages B-18 through B-22 [not reproduced in this report].

COMMENTS ON SAMPLING - The methods used by the Contractors's quality control organization are quite different than normally used by the Corps of Engineers. A sample is usually split on the No. 4 sieve and representative material larger than the No. 4 sieve size is screened through a vibrating Gilson [shaker]. A small sample (say 500 grams) of representative minus No. 4 material is tested for the finer fraction. Two gradations are normally provided. The CQC ran their samples on the three fractions - 6-in. to 1/2-in., 1/2-in. to No. 4, and minus No. 4, and then converted everything back to total sample values, including a fudge factor to account for fines clingin to rocks.

CONCLUSIONS - The test fills indicated that the materials as being excavated are such that they cannot be placed into the embankment without selective loading and processing and that they do contain too many fines to be used under the present specifications without excessive processing. These tests, however, reflect the material as pit-run material and although they appear to be representative of the basalt excavation, it is not felt that they are necessarily representative of material available if some attempt were made to improve the gradation. The percentage by weight of the entire sample passing the No. 200 sieve averaged about 7 percent.

Specifications for Type I rock fill require not more than 20 percent by weight passing the 1/2-in. screen of the 6-in. minus material. On this basis, the five samples indicated an average of approximately 50 percent by weight passing the 1/2-in. screen. This is more than double the allowable percentage per the specifications so there is a real and urgent problem involved.

The Contractor has, as far as is known, made very little effort at selective loading as he excavates. Neither has he attempted to control rock sizes with different blasting techniques. Discussion with Mr. Lou Oriard of Woodward Clyde, relative to the slurry type explosive being used by the subcontractor, indicated that much more energy is available from this type explosive and the question immediately arises as to whether or not the rock is being shattered and much more minus 1/2-in. material is being generated than necessary. All material from excavation seems to be extremely variable and methods of excavation, loading, etc. cause segregation and thus worsens the end product. It appears that if different meghods of blasting, loading, handling and hauling of materials were investigated, the Contractor could substantially improve the gradation of the material being produced.

Material hauled into the test fills, for example, varied from loads of clean, coarse rock to exceptionally dirty loads of rock and soil. Better blending of these materials would have provided gradations much nearer to those required. The samples taken were of the dirtier materials and do not reflect the clean coarse rock. Selective loading and washing of dirtier loads by placing in random zones will be necessary throughout the excavation and it is anticipated that rock rakes will be necessary on the embankment to help sort materials. Even with such controls, it is felt that specification requirements are too restrictive fro volcanic materials such as are available at the site.

DISCUSSION AND RECOMMENDATIONS - There are many means of controlling the gradations of materials to go into a structure such as Ririe Dam. The most desirable, however, are those which are relatively easy for the project inspectors to control and the recommendations as set up will be made with these people in mind. Following are discussions of changes which will help to accomplish this end:

(1) The upstream random fill zone will be changed to permit a larger volume of random materials. The new control will be a vertical line from the slope break at Elev. 5050. The entire embankment upstream of this vertical line will be random materials except for special zones such as a rock drain 50 ft wide and 10 ft high extending from the spalls to the face of the embankment with the invert at Elev. 5010 and centered on the radial Station 5+00, special treatment zones over interbeds and slope protection. Material

as available from the random borrow area upstream shall be used to the maximum extent possible in the random fill zones.

(2) Between the core and filters (and spalls) both upstream and downstream and the vertica limits through the slope breaks at Elev. 5050 and below Elev. 5050, Type I rock fill requirements will be changed to require not more than 25 percent by weight passing the 1/2-in. screen of the entire sample. This gradation will be called Type 1B rock fill to distinguish it from Type I, hereafter called Type 1A rock fill. All Type I rock fill, either A or B, will come from basalt rock excavation as before. Selective loading will be necessary to meet this requirement, but it is felt that regardless of what control is set, it will be necessary for the Contractor to do at least a normal amount of selective loading. Previously, it was suggested to the Contractor that all material be separated on the 10 or 12-in. screen and that the minus 12-in. material containing less than 12 percent by weight passing the standard No. 200 sieve be placed as granular fill in 12-in. lifts in Type I rock-fill zones. The consensus was that this involved too much processing as a large portion of the material would have to go over a grizzly. It may be that some of this type handling might become desirable, however, because it would permit the Contractor to place coarser material (either Type IA or IB rock fill) downstream of the core and filters and granular material, as defined above, upstream of the core and filters.

In discussion with Messrs. Anderson and Bubenik of NPD, they expressed an interest in varying lift thickness for these materials with controls on the 1/2-in. screen. Three different controls were discussed as follows:

(a) For material with less than 20 percent by weight passing the 1/2-in. of the entire mass, place in 3-ft lifts with two passes of the 20-ton vibratory roller.

(b) For materials having more than 20 percent, but less than 30 percent by weight of the entire mass passing the 1/2-inch, place in 2-ft lifts with two passes of the 20-ton vibratory roller.

(c) For materials having over 30 percent by weight of the entire mass passin the 1/2-in. screen, place in 1-ft lifts with two passes of the 20-ton vibratory roller.

For such a system of control, it would become necessary to place 3-ft lifts in one zone, two foot lifts in another and the 1-ft lifts in yet a third, possibly the random zone. Such a method of control makes it extremely difficult for the USCE inspectors and would probably result in an unsatisfactory end result. Consequently, it is recommended and agreed to by NPD that just one control be used, namely, not over 25 percent shall pass the 1/2-in. screen of the entire sample for the Type 1B rock fill below Elev. 5050 and above Elev. 4965. Placement shall be in three-foot lifts and compaction with two complete passes of a 20-ton vibratory roller.

(3) The Contractor stated that they will place gravel fill to Elev. 4965 upstream and downstream of the core and filters to level the area out and permit faster placement above that leve, and it is assumed that this is still his intent.

(4) Above Elev. 5050, Type 1A rock fill as originally specified or gravel fill may be used at the option of the Contractor. If gravel fill is used, the outer ten feet of the upstream slope shall consist of rock fill, five feet of clean Type IA rock fill behind five feet of riprap (measurements horizontal).

(5) Material originating from basalt excavation containing over 25 percent, but less than 35 percent by weight of the entire sample passing the 1/2-in. screen may be placed in the random fill zone in two-foot lifts and compacted with two passes of the 20-ton vibratory roller.

(6) The above recommendations are considered to be the farthest we can go toward relaxing our specifications to help the Contractor and to permit more of the available material to be used in the embankment. From a design standpoint, the previous suggestion of splitting the material on the 10 or 12-in. and setting up a granular fill section upstream of the core and filters with Type 1A rock fill downstream is still the preferred method of attack. This is the safest approach and very probably would be the least costly and easiest to control. Processing would be required, but once the material had been passed over the grizzly, there would be no more problem relative to gradation thereof.

(7) It is highly recommended that before any commitment is made to the Contractor, a test blast or two be used to assure that the current method of excavation is not pulverizing the rock and causing the problem. If the test blasts indicated that better material could be produced by better blasting,

then the controls for rock fill should be lowered to not over 20 percent by weight of the entire sample passing the 1/2-in. screen. Material with more than 20 percnet but less than 30 percent by weight of the entire sample passing the 1/2-in. screen should then be permitted in 2-ft lifts in the random zone. All compaction should consist of two complete passes with a 20-ton vibratory roller.

APPENDIX D: CONTRACTOR QUALITY CONTROL TESTING REQUIREMENTS

(Taken in its entirety from US Army Engineers 1978)

1. The Contractor will be required to sample and test the various earthwork materials as often as necessary to provide materials which conform to specifications. A recheck test will be required for any material which does not meet specifications. It is recognized that the number of tests required to insure control of materials may vary considerably, with a greater number of tests during initiation of construction, and fewer tests as construction methods stabilize and experience dictates. Written results of all tests shall be delivered to the Contracting Officer's Representative within 24 hours of the completion of the test. A verbal report of any test showing the material tested fails to meet the applicable specification shall be given to the Contracting Officer's Representative immediately after the results of the test is shown.

2. To provide a guide for testing requirements, a minimum number of gradation tests for each type of material to be placed in the embankments is as follows:

- a. Foundation Blanket -- one complete gradation for each 250 cu yd of material, but not less than one per shift.
- b. Impervious Core and Impervious Fill -- one complete gradation for each 1000 cu yd of material but not less than one per shift.
- c. Filter Materials, Impervious Gravel, and Spalls -- one complete gradation for each 500 cu yd of material, but not less than one per shift.
- d. Sub-base Material -- one complete gradation for each 200 cu yd of material.
- e. Road Surfacing Materials -- as specified in the TECHNICAL PROVISIONS.
- f. Rock Fill -- as specified in the TECHNICAL PROVISIONS.
- g. Gravel Fill -- one complete gradation for each 1,000 cu yd of material, but not less than one per shift.
- h. Slope Stabilization -- one complete gradation for each 1,000 cu yd of material, but not less than one per shift.
- i. Random Fill -- one complete gradation for each 5,000 cu yd of material.
- j. The Contractor shall make such gradation tests of materials to be stockpiled as are necessary to assure himself that the material will meet specification requirements when placed in embankments or other final position.

3. All gradations shall be complete through the No. 200 sieve size. Moisture content and laboratory compaction tests are dependent upon the

Contractor's method of operation. If fine-grained materials are stockpiled, they will require suitable testing to assure optimum moisture requirements are met at the time of stockpiling. The Contractor shall develop families of laboratory compaction curves for each change in material to properly control moisture content in stockpiles and in embankments. This may require a large number of tests at the start of the work and a lesser number of tests as experience with the material is gained. The Contractor shall at all times take sufficient tests, in the opinion of the Contracting Officer, to maintain positive control of his work, and the minimum number of tests stated above shall in no way limit the maximum number of tests which may be required to assure suitable control. Additional tests above the minimum number stated shall not be the basis for changed conditions and resultant claims, and it shall be understood that all quality control testing is incidental to and included in the appropriate embankment items.

APPENDIX E: SUMMARY OF LOCATIONS FOR RECENT ENGINEERING STUDIES AND SEISMIC GEOPHYSICAL MEASUREMENTS

Table E1

Summary of Recent Explorations

Type	New Designation	Old Designation	Coordinates (ft) Northing	Coordinates (ft) Easting	Elevation (ft)	Maximum Depth (ft)	Dates	Drilling Crew	Purpose
Rotary	DH-258	WES-1	698,887*	611,860*	4970*	115	8/3-10/84	WES	SPT
5"Odex	DH-259	WES-2	698,678	611,917	4971	88	8/21-24/84	"	XH Seismic
"	DH-260	WES-3	698,671	611,909	4971	98	8/20/84	"	"
"	DH-261	WES-4	698,401	612,427	5082	118	8/31-9/3/84	"	"
"	DH-262	WES-5	698,394	612,423	5082	120	8/27-30/84	"	"
8'Auger	TS-1	None	698,728	612,104	4993	73	7/24/84-8/9/85	ESA/Case	Density
Cone	CPT-1	RD-C-1	698,373	612,534	5128	72	11/14/84	ERTEC	CPT/DH Seismic
"	CPT-2	RD-C-2	698,503	612,589	5128	128	11/8/84	ERTEC	CPT/Pore Press.
"	CPT-3	RD-C-3	698,428	612,559	5128	150	11/15/84	ERTEC	CPT/DH Seismic
6"Odex	DH-263	DH-260	698,702	612,120	4995	239	9/6-13/86	NPP	XH/DH Seismic
"	DH-264	DH-261	698,713	612,123	4995	139	9/18-19/86	NPP	DH Seismic
"	DH-265	DH-262	698,724	612,128	4994	138	9/21-25/86	NPP	DH Seismic
Rotary	DH-266	DH-261A	698,547	612,059	4996	254	10/31-12/8/86	NPP	DH Seismic/SPT
Becker	BCC 86-1	same	698,850	611,866	4970	71	9/17/86	Becker	BPT
"	BCC 86-2	"	698,686	611,895	4970	71	9/17/86	"	"
"	BOC 86-2	"	698,702	611,911	4971	68	9/19/86	"	"
"	BCC 86-3	"	698,876	611,978	4971	83	9/17-18/86	"	"
"	BOC 86-3	"	698,857	611,972	4970	85	9/18/86	"	"
"	BCC 86-4	"	698,615	612,163	4998	107	9/19/86	"	"
"	BOC 86-4	"	698,636	612,166	4998	108	9/26-27/86	"	"
"	BCC 86-5	"	698,735	612,195	4995	98	9/19-20/86	"	"
"	BOC 86-5	"	698,767	612,203	4995	93	9/20/86	"	"
"	BCC 86-6	"	698,581	612,060	4995	83	9/22/86	"	"
"	BOC 86-6A	BOC 86-6	698,601	612,069	4995	60	9/22/86	"	"
"	BOC 86-6B	same	698,557	612,053	4996	107	9/22-23/86	"	"
"	BCC 86-7	"	698,701	612,090	4995	97	9/23/86	"	"
"	BOC 86-7	"	698,684	612,108	4995	98	9/25/86	"	"
"	BCC 86-8	"	698,821	612,126	4994	90	9/23-25/86	"	"
"	BOC 86-8	"	698,797	612,129	4994	104	9/25-26/86	"	"
"	BCC 86-9	"	698,495	612,125	5005	69	9/26/86	"	"
"	BOC 86-9	"	698,515	612,131	5003	68	9/27/86	"	"

* Estimated based on tape measurement and interpolation.

Table E2

Summary of Permanent Exploration Casings

	Coordinates (ft)		Elevation (ft)			Material and		
				Casing				
Drillhole	Northing	Easting	Ground	Top	Bottom	Diameter	Type	Other
DH-259	698,678	611,917	4971	4973	4883	5" steel	Solid/Open	Odex Casing
DH-260	698,671	611,909	4971	4973	4873	"	"	"
DH-261	698,401	612,427	5082	5086	4965	"	"	"
DH-262	698,394	612,423	5082	5086	4962	"	"	"
DH-263	698,702	612,120	4995	4996	4779	4" pvc	Solid/Capped	6"hole/grout
DH-264	698,713	612,123	4995	4996	4857	"	"	"
DH-265	698,724	612,128	4994	4995	4857	"	"	"
DH-266	698,547	612,059	4996	4997	4745	"	"	5-5/8"hole/grout

APPENDIX F: REPORT SUBMITTED BY EARTH SCIENCE ASSOCIATES

(September 1985)

TEST SHAFT AND
SOIL DENSITY TESTING
AT RIRIE DAM

for

U.S. Army Corps of Engineers
Walla Walla District
Building 602, City-County Airport
Walla Walla, Washington 99362

by

Earth Sciences Associates
701 Welch Road
Palo Alto, California 94304

Contract No. DACW68-84-C-0075
Services for Soil Exploration and Sampling
at Ririe Dam, Ririe, Idaho

ESA Project 3046 September 1985

Earth Sciences Associates

TEST SHAFT AND SOIL DENSITY TESTING AT RIRIE DAM

Table of Contents

Earth Sciences Associates

I INTRODUCTION

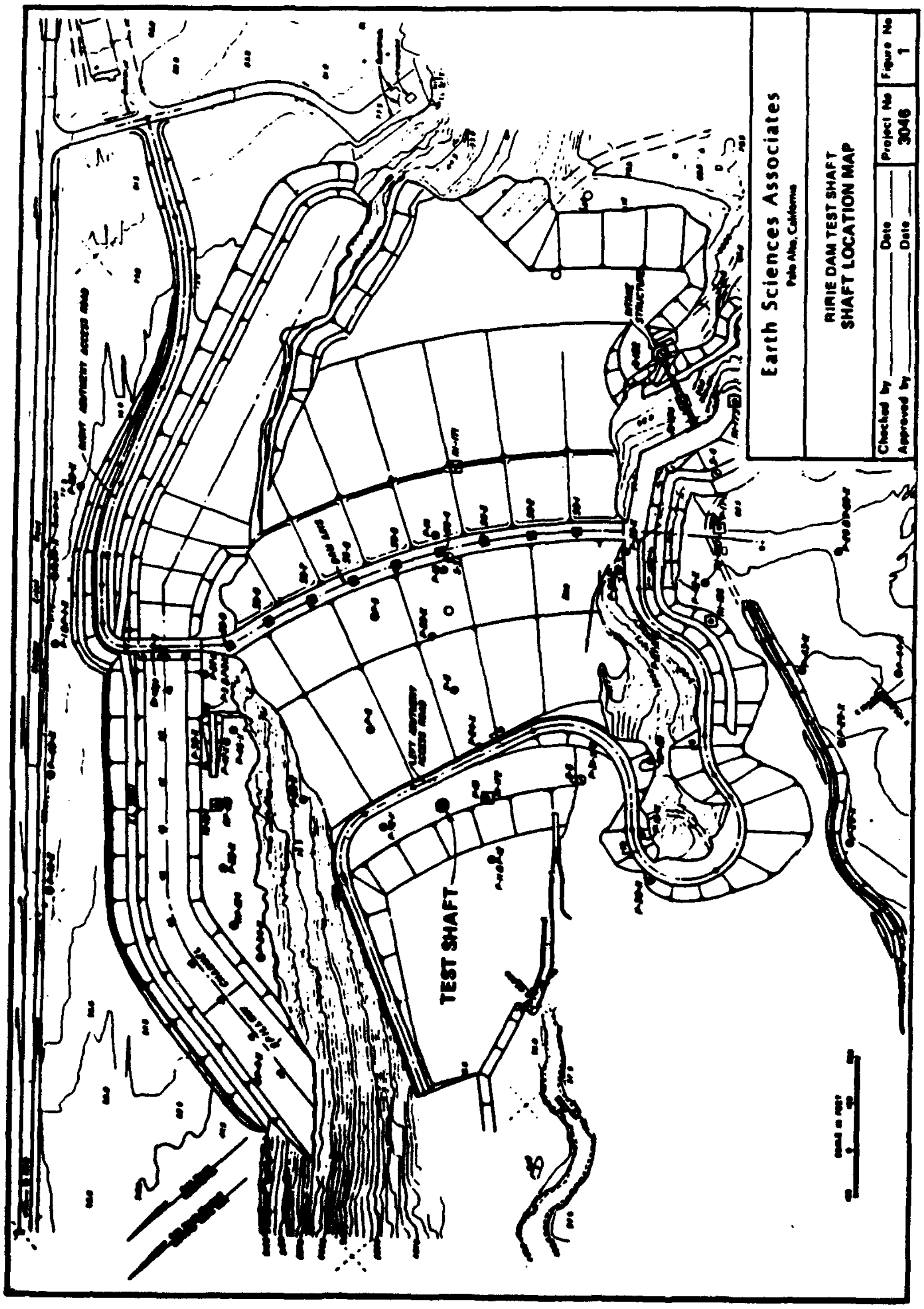
This report presents the results of a program of soils exploration and sampling at Ririe Dam, Ririe, Idaho. The program included excavation of an 8-foot diameter shaft on the downstream berm of the dam for the purpose of obtaining large in-situ density tests and samples of soils in the Random Fill zone of the berm and the alluvium in the foundation (Figure 1). Samples were sieved on site, bagged, and shipped to the USAEC Waterways Experiment Station in Vicksburg, Mississippi. In order to advance the shaft and take density tests, it was necessary to dewater the site, an operation that proved to be more difficult than anticipated and which set the limits on the depth of the shaft and number of samples obtained. The shaft was excavated through 39 feet of bouldery Random Fill and 33.8 feet of gravelly alluvium for a total depth of 72.8 feet. A total of 8 in-situ density tests were conducted in the shaft, including a test in the Random Fill zone and 7 tests in the foundation alluvium. In addition, one large bulk sample was obtained from the bottom of the shaft.

The work was conducted under Contract No. DACW68-84-C-0075, Services for Soils Exploration and Sampling at Ririe Dam, Ririe, Idaho between the Walla Walla District, Corps of Engineers and Earth Sciences Associates, Palo Alto, California. Mr. Fred Miklancic, Chief, Foundation and Materials Branch, was Authorized Representative of the Contracting Officer and Mr. Grady Williams acted as field representative for the District. Richard C. Harding was Project Manager for Earth Sciences Associates and Mr. T. Dwight Hunt, Senior Engineering Geologist, supervised operations at the site. Case Pacific Company, subcontractor to ESA, excavated the shaft, and Andrew Well Drilling Contractors, Idaho Falls, was the dewatering subcontractor.

II METHODOLOGY

A. Shaft Excavation

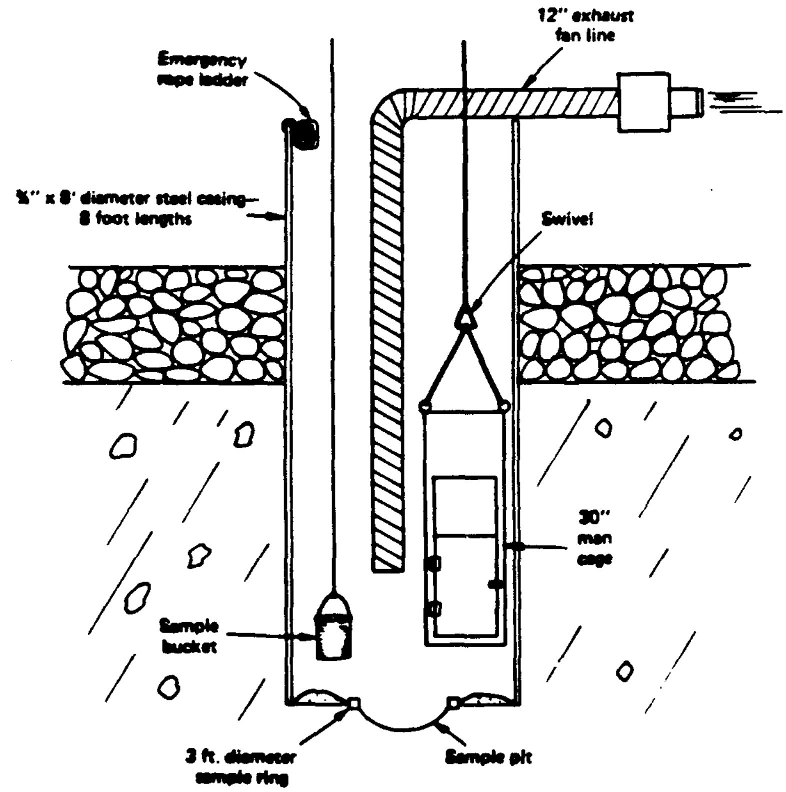
The test shaft was excavated on the level berm downstream of the left abutment access road at approximately Station 8+00 (see Figure 1). After clearing rip-rap from the surface of the berm, the shaft was excavated with a Watson 5000 auger drilling unit mounted on a 60-ton crane. Support equipment included:


Earth Sciences Associates
Palo Alto, California
RIRIE DAM TEST SHAFT
SHAFT LOCATION MAP
Checked by
Date
Approved by
Date
Project No
3046
Figure No
1
TEST SHAFT

5'-0" auger w/reamers
5'-0" bucket w/reamers
Personnel cage
Gas detection equipment
Fresh air blower
Lighting
Safety harness
Rope ladder
Front-end loader
Welding machines (2)
Pick-up trucks (2)
Oxy-acet. cutting outfit
Internal dewatering pump
Auger and bucket teeth
Storage unit
20 ton center mount hydraulic crane (power up and down)
Caisson bucket
Temporary sanitary facilities
Fuel truck
Service truck

Steel casing, 8-foot diameter with 3/4-inch wall thickness, was installed as the shaft was advanced. A shaft cover, constructed of steel mats, was hoisted over the shaft at night for security. To obtain in-situ density tests at selected intervals in the bottom of the shaft, personnel were lowered into the shaft in a man-cage. When outside of the cage, personnel wore safety harnesses attached to ropes from the surface. In the event of an emergency, they could be hoisted out of the shaft by hand, without having to get back in the cage or having to rely on the crane winch. In addition, a rope ladder was available for added safety. Fresh air was maintained at the bottom of the shaft by means of a fan line (see Figure 2).

Excavation through the Random Fill zone proved to be very difficult owing to unanticipated large boulders. Many of these boulders, ranging in size up to 4-5 feet, could not be removed with the drilling equipment and required putting men in the shaft to hand-excavate and remove them with cable slings.



NOTES:

1. Casing to be installed in 8 ft. lengths and welded onsite.

2. A hole cover manufactured from larger casing will be hoisted over shaft at night for security.

3. Upon completion of hole, casing will be left in hole and hole will be backfilled with spoil in 2-3 foot lifts and compacted by dropping Kelly bar with auger attached.

Earth Sciences Associates Palo Alto, California		
RIRIE DAM TEST SHAFT **SHAFT DESIGN**		
Checked by ______ Date ______ Approved by ______ Date ______	Project No. [illegible]	Figure No. 2

The shaft was advanced to a depth of 54 feet between July 24 and September 5, 1984, when the excavation was halted because groundwater was encountered (see next section). The shaft excavation was halted through the 1984-1985 winter season, while additional dewatering wells were installed. It was decided that the in-place 8-foot casing would be too difficult to advance after resting in the bouldery fill over the winter. The remaining casing on-site was shipped to a fabrication yard and rerolled to 7-foot diameter in order to complete the shaft by telescoping the smaller casing through the in-place casing when the project was remobilized in the summer of 1985. Spacers were used to minimize binding of the smaller casing inside the larger, and a special driving head was built to work inside the 8-foot pipe. This procedure worked successfully, and the shaft was advanced to a depth of 72.8 feet, when it was again halted by groundwater.

B. Dewatering

Groundwater at the site occurs as perched zones within the random fill and as a water table within the foundation alluvium. The most prominent zone of perched water occurred in a 2-4-foot thick zone above a silt lens at a depth of 32 feet. Water from this perched zone seeped into the shaft at an estimated rate of less than 1 gallon per minute. The natural groundwater level during the summers of 1984 and 1985 was at a depth of approximately 44 feet below the surface of the berm. The saturated alluvium extends to a depth of approximately 115 feet where relatively imperious volcanic bedrock is encountered.

Data from pump tests and other exploration conducted by the Corps of Engineers prior to construction of the dam indicated that the average permeability of the alluvium is on the order of 0.05 feet/min. Based on this information, calculations using standard well formulas indicated that dewatering wells with a combined pumping capacity of 1500 gpm would be necessary to achieve drawdown in the shaft to a depth of about 100 feet. It was recognized that it would not be possible to completely drawdown the water level to the bedrock surface.

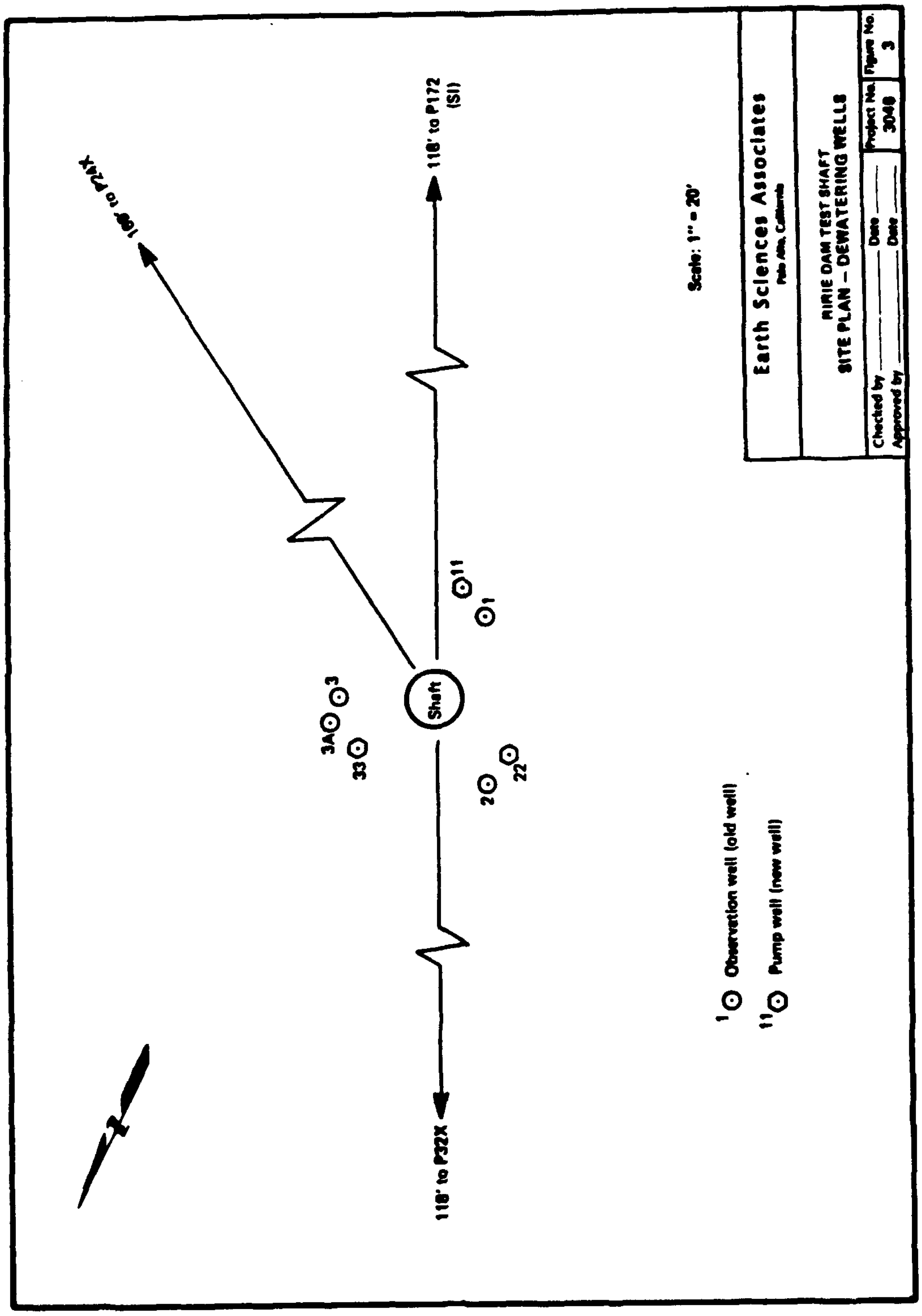
On the basis of these calculations, three dewatering wells, spaced evenly around the shaft, each with a pumping capacity of 500 gpm, were specified. The dewatering subcontractor installed the three wells using an air-rotary rig, and driving steel casing as the wells were advanced. He then perforated the casings with a down-hole perforator. The wells were designated #1, #2 and #3A (#3 was abaondoned because of difficulty drilling through boulders) as shown on Figure 3.

Pumping was started when the shaft excavating equipment was mobilized in July 1984. The initial pumping rate from the three wells was about 900 gpm, but the rate decreased rapidly and stabilized at about 300 gpm. After pumping for several weeks, drawdown of only about 10 feet was achieved in the shaft, although pumping levels in the wells were at depths of about 100 feet. After encountering water at a depth of 54 feet, excavation of the shaft was halted.

Calculations based on pumping rate and measured drawdown indicated a permeability of .06 ft/min for the alluvium. Recovery curves after the pumps were shut down indicated a permeability of .04 ft/min. These values were consistent with the previously determined value of .05 ft/min.

After surveying the well casings with a down-hole video camera, it was determined that the perforations did not provide sufficient open-space for well efficiency. The dewatering subcontractor attempted to re-perforate the wells, but only increased the stabilized pumping rate to about 400 gpm. After additional attempts to re-perforate the casing resulted in the collapse of one of the casings (#2), this method was abandoned.

The well subcontractor was then instructed to install three new wells with well screens extending from 60 feet to 115 feet depth, and with the wells bottomed 15 feet into bedrock. Based on gradation curves of samples from the wells, indicating 42% retained on 3/8-inch screen and 58% retained on 1/4-inch screen, well screens with a slot width of .18 inches and a minimum open area of 200 in^2 per foot were specified.


Earth Sciences Associates
RIRIE DAM TEST SHAFT
SITE PLAN – DEWATERING WELLS
Checked by
Date
Approved by
Date
Project No.
3048
Figure No.
3
Scale: 1" = 20'
118' to P172 (SI)
118' to P32X
Shaft
1
11
2
22
3
3A
33
Observation well (old well)
Pump well (new well)

After the new screened wells (designated #11, #22 and #33) were installed and developed, a 4-day pump test was conducted by pumping the 3 wells simultaneously between November 29 and December 3, 1984. Pumping quantities were measured with a flow meter installed in the discharge manifold. Drawdown was measured in observation wells consisting of two of the old wells, #1 and #3A (#2 had collapsed when attempting to re-perforate the casing, and could not be used for monitoring), piezometer #P24X, and slope indicator #P172. #P32X was measured initially, but because of its shallow depth, it soon went dry (see Figure 3).

Pumping rates were high initially, over 1500 gpm, but after about 20 minutes decreased to about 1000 gpm. After about 4 hours, the rate had begun to fluctuate between about 350 and 1100 gpm, indicating that the wells were sucking air and surging. After closing the discharge valves somewhat, the surging stopped, but the pumping rates continued to decline to about 350 gpm after 4 days.

We believe this decrease in pumping rates results from three principal factors: (1) as drawdown increases, the effective transmissibility decreases because the wells have a decreasing thickness of saturated formation to draw from; (2) as the drawdown cone steepens, vertical permeability of the formation, which is probably less than horizontal permeability, becomes a more significant factor; and (3) as the drawdown cone widens, boundary conditions, consisting of the sloping bedrock walls of the canyon, the cutoff wall of the dam, and recharge from the river downstream, come into effect. In order to evaluate the effect of the boundary conditions and other factors, a computer model was used based on the method of image wells.

The effectiveness of the new dewatering system was evaluated using a computer program developed by ESA which calculates the unsteady state drawdown of an extensive confined aquifer being pumped by a series of constant discharge wells. The program calculates the drawdown at a point due to a constant pumping (or recharging) well by solving the equation:

$$h_o - h = Q/(4\pi T)\int_u^{\infty}(e^{-u}du)/u$$

where $u = r^2S/4Tt$ and

Q = the constant well discharge
T = coefficient of transmissibility (T = Kb; K = permeability and b = saturated thickness)

t = time since pumping began

s = storage coefficient

r = distance from point to well

This equation is known as the nonequilibrium or Theis equation. The program can simulate the effects of impervious and/or stream (or constant head) boundaries using image wells. Assumptions and methodology regarding the analysis procedure is discussed in Todd (Todd, "Ground Water Hydrology," John Wiley & Sons, Inc., 1959, pp. 78-114).

For an unconfined aquifer. the specific yield of the formation is substituted for the storage coefficient.

It should be noted that the drawdowns computed from the equation above are nearly correct for an unconfined aquifer as long as the drawdown is small in comparison with the saturated thickness. In the cases of the drawdowns measured at Ririe Dam during pumping, the saturated thickness is being changed rather significantly, especially near the pumping wells. In addition, the pumping rates of the wells change with time as the drawdowns in the wells increase, as was previously mentioned.

In order to try and compensate for the difference between the actual field conditions and the assumptions used in the model, transmissivities and pumping rates were "averaged" over the time period of interest. An average permeability of 0.05 ft/min was used in all runs of the model. The model was first calibrated as closely as possible (and practical) to the drawdowns measured in several piezometers/wells during the pumping of the newly developed wells. Once the model was calibrated to actual field conditions, drawdowns were calculated for additional periods of time to project the

effectiveness of the new dewatering system. Results of our model study are summarized in the table below:

COMPARISON OF PREDICTED DRAWDOWN
FROM COMPUTER MODEL AND
MEASURED DRAWDOWN FROM 4-DAY PUMP TEST

Days (Min)	Avg Q GPM	Observation Well	Predicted Drawdown (Ft)	Measured Drawdown (Ft)
1.33 (1915)	525	#1	20.1	27.0
		3A	19.2	37.5
		P24X	9.5	7.0
		Shaft	19.7	—
4.33 (6235)	420	#1	25.0	31.0
		3A	24.0	38.5
		P24X	14.8	11.0
		Shaft	24.5	—
7.00 (10.080)	397	#1	28.3	
		3A	27.4	
		P24X	18.4	
		Shaft	27.8	
14.00 (20,160)	373	#1	34.7	
		3A	34.0	
		P24X	25.3	
		Shaft	34.3	

The table shows that the model underestimates the drawdowns actually measured during the pump test, i.e., for dewatering purposes, the model is conservative. The model also indicates that the drawdown in the shaft should be approximately the same as the drawdown in the close observation wells #1 and #3A. The model predicts that the drawdown in the shaft should be about 34 feet after 14 days of pumping. With the static water level at a depth of 44.5 feet, the predicted drawdown in the shaft would be at a depth of 78.5 feet. It should be noted that the actual drawdowns measured in the close observation wells after 4 days pumping ranged from 31 to 38.5 feet.

Based on the results of the computer model study, it was decided to remobilize the excavation equipment in the summer of 1985 to deepen the shaft and obtain additional samples. The pumps were started on July 17, 1985, two weeks before the excavation equipment was mobilized, in order to allow time for sufficient drawdown. Within two weeks the pumping quantity had stabilized at about 330 gpm, with water levels in the pump wells and

observation wells as follows:

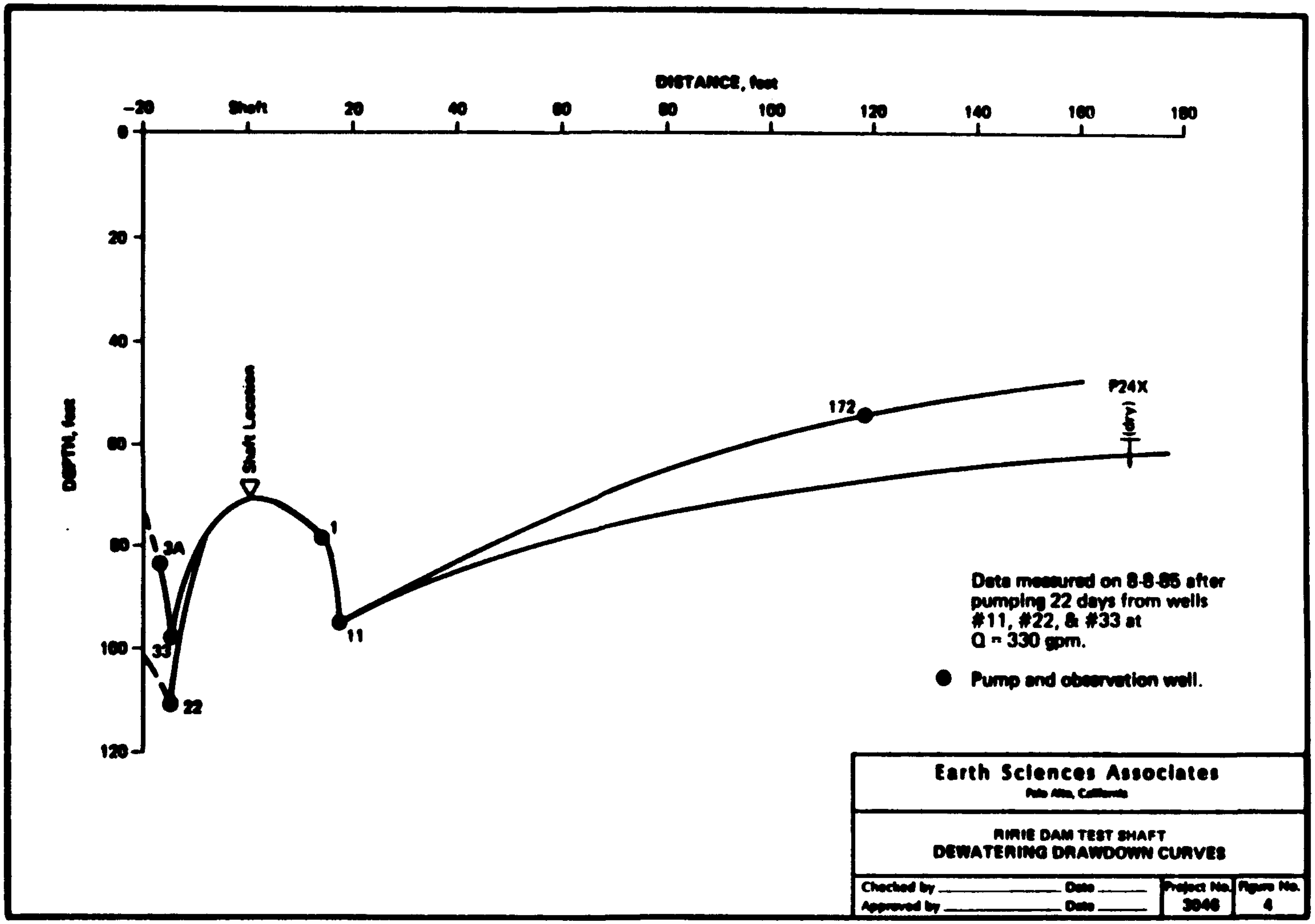
Pump Well	Water Depth Below Surface Datum	
#11	95.0'	
#33	97.7'	
#22	111.0'	
Observation Well		
# 1	78'	
# 3A	83.4'	
#P172	54.4'	
#P24X	Dry at 58.9'	(Total depth of piezometer)

The computer model and previous pump test results had indicated that the drawdown in the shaft should be about the same as the drawdown in monitoring well #3A. Therefore, it was hoped that the shaft could be excavated to a depth of at least 80 feet. Nevertheless, groundwater was encountered in the shaft at a depth of 67.6 feet. A sump pump was installed in the shaft, which lowered the water level enough to take density test #8, but could not draw down the water sufficiently to advance the shaft further. A bulk sample of saturated gravels was taken, which brought the final shaft depth to 72.8 feet.

Drawdown curves, based on measurements taken August 8, 1985 (22 days after pumping began) are plotted on Figure 4. The curves are much steeper in the vicinity of the shaft than outside of the area of the pump wells. Given the fact that the three pump wells are spaced evenly around the shaft, the steeper curves near the shaft are opposite of what would be expected or was predicted by the computer model.

C. Density Test Procedures

Eight in-place density tests were performed in the exploratory shaft, and excavated material from the tests was sieved for grain size determinations. A large volume bulk sample was obtained from the bottom of the shaft for laboratory analysis by the COE. The sampling procedures are described below.


DISTANCE, feet
−20
Shaft
20
40
60
80
100
120
140
160
180
DEPTH, feet
0
20
40
60
80
100
120
Shaft Location
3A
33
22
1
11
172
P24X
(dry)
Data measured on 8-8-85 after pumping 22 days from wells #11, #22, & #33 at Q ≈ 330 gpm.
Pump and observation well.
Earth Sciences Associates
Palo Alto, California
RIRIE DAM TEST SHAFT
DEWATERING DRAWDOWN CURVES
Checked by ____ Date ____
Approved by ____ Date ____
Project No. 3046
Figure No. 4

1. Density tests

A 3-foot diameter by 6-inch high flanged steel ring was used for a perimeter base within and below which in-place sample material was excavated. Materials disturbed by auger drilling were excavated by hand in order to prepare a level surface in undisturbed soil upon which the ring was placed. A thin rubber membrane (cut from a weather balloon) was placed over the ring and secured with an elastic cord. Water was poured in the membrane, with the volume measured by two calibrated flow meters. The volume was calculated to the nearest 1/10 of a gallon after filling the ring to within 1 or 2 inches of the top. The level of the water was measured precisely from a point on the top of the ring. The water was then evacuated and disposed of outside of the shaft. The rubber membrane was removed, and excavation of sediments within the ring commenced. Attempts were made to excavate approximately 900 pounds of material. Sloughing of material underneath the rim of the sample ring during excavation of samples #2 and #4 prevented deeper excavation which would have been required to obtain this desired weight.

After excavation, the rubber membrane was again placed over the ring and refilled with water up to the previous level. This volume of water was then recorded from which the previous water volume was subtracted. The difference between the two volumes constitutes the volume of the sample excavated. It is estimated that the volume of water is from .5 to 1.5 percent less than the true volume of the removed sample, due to slight non-conformity of the membrane over the rough relief of the cavity walls. Following the volume determination, the water was again evacuated and disposed of outside the shaft.

The freshly excavated sample was weighed immediately, then spread out to air dry. The dry density of the sample was determined after oven-drying a smaller, representative sample of the material and calculating the moisture content as described below.

2. Moisture content

Prior to air drying, a representative sample of the material (20 to 30 pounds) was selected for moisture content analysis. This sample was placed in three shallow pans and oven dried to a constant weight (generally 12 to 24 hours). When dried, the sample was removed from the oven, allowed to cool, and re-weighed. The difference of the wet weight minus the dry weight (excluding pan weights) divided by the dry weight of the sample is the moisture content of the sample. This figure is used to calculate the dry weight (dry density) of the sample:

$$\text{dry density} = \frac{\text{wet density}}{1 + \text{moisture content}}$$

Additional moisture content determinations were performed on air-dried materials from sample numbers 5 and 8. These analyses were made to check the degree of moisture remaining in the samples prior to sieving and packing for shipment. The moisture contents of the air-dried samples were 2.2% and 1.5% for samples 5 and 8, respectively. It is estimated that for the air-dried portions of the eight density samples, the moisture content ranged from 1% to 3% at the time of sieving.

3. Sieve analyses

After air and oven drying of the density samples, the material was re-weighed, then sieved through an automatic Gilson shaker with the following sieve sizes utilized: 6-inch, 3-inch, 1½-inch, and ¼-inch (#4).. Material passing the ¼-inch sieve was collected in a pan. The various sizes of material were bagged separately using rubber-lined canvas bags of approximately 100-pound capacity. The entire bagged sample was re-weighed to check any change after the sieving process, owing to loss of dust (silt and clay-sized particles).

4. Bulk sample

At a shaft depth of 70.3 feet, it was concluded that the ground water level would prevent further density sampling. At the COE's

request, a bulk sample of approximately 2,500 pounds was obtained by bucket auger drilling to a depth of 72.8 feet (bottom of the bucket). The bulk sample material was air dried and crated for shipping without weighing.

III SUBSURFACE CONDITIONS

A. Random Fill Zone

The embankment fill at the shaft site is approximately 40 feet thick and consists of inhomogeneous to sharply stratified zones of silt, gravel and boulders. Generally, the fill material grades finer with depth.

The upper 32 feet of fill are characteristically coarse with abundant angular cobbles and boulders ranging up to 5 feet in size. Non to low plasticity fines commonly comprise one-third of the volume, with fine to coarse sand and gravel typically one-half to three-fifths of the volume. Large boulders are most abundant in the 0- to 12-foot and 18- to 29-foot depth intervals.

Most of the material above the 32-foot depth is moist, with local wet or saturated zones where presumably surface water percolation is perched on finer grained lifts. The most prominent saturated zone occurs between 29 and 32 feet. The most conspicuous change in fill material occurs at a depth of 32 feet, below which silt comprises typically two-thirds or more of the volume with minor gravel and scattered boulders. This material is significantly drier, ranging from damp to moist. Gravel clasts below the 32-foot level are predominently rounded, while those above are commonly angular. Organic roots and fibers are also present below 32 feet.

B. Alluvium

As interpreted from the dewatering well borings (see Appendix), the natural alluvium below the embankment fill extends to a depth of approximately 115 feet below the surface where basaltic bedrock was encountered.

The uppermost alluvium exposed in the shaft excavation is a uniform, massive silt, differentiated from the overlying silty fill by abundant unbroken roots and bedding planes. Within a few feet of the fill contact, sandy interlenses appear, and at 45.7 feet, a sharp bedding contact with gravel is present. Locally stratified and interlensed deposits of silt, sand and gravel were exposed to a depth of approximately 50 feet, below which generally massive silty and sandy gravels were encountered to the limits of the shaft excavation. Below approximately 50 feet, the fine gravel matrix consists of a silt or clayey silt of low plasticity. The sand fraction is typically well graded (poorly sorted) from very fine to coarse grained, with skip-graded to well graded gravels. Occasional cobbles and boulders in excess of six inches are scattered throughout. The materials excavated below approximately 50 feet displayed a striking resemblance to a wet, lean concrete mix when dumped at the surface.

The sand and gravel deposits are typically medium dense to dense, generally massive, but locally crudely stratified with imbrication of gravel clasts locally, and uncemented. Clasts are predominantly rounded to well rounded and commonly flattened. The lithology of the gravels include abundant basaltic clasts derived from rocks similar to the volcanic flow rocks underlying this region, as well as sedimentary and metasedimentary clasts, including quartzite, secondary quartz, limestone and chert derived from upland regions to the southeast.

Based on hand excavation experience, the material below approximately 50 feet can be field classified as medium dense to dense. Excavation of these materials by hand is feasible, but somewhat difficult due to the dense packing resulting from the wide range of grain sizes. A clean exposure of the natural deposits (generally limited due to casing cover, slough cover, or auger disturbance) observed below the casing from 66.8 to 70.3 (see photos) revealed massive, uncemented sand and gravel deposits which were very dense. Clasts could be removed by hand, but with difficulty. Excavation of sample #8 (66.4 to 67.8 feet) encountered these very dense sediments, the excavability of which was slightly more difficult, but not significantly different than the excavability of samples 4 through 7.

The alluvial sediments below 72.8 feet were not sampled, but dewatering well drilling indicates predominantly massive sand and gravel to be present nearly to the bedrock depth at approximately 115 feet. A reddish-colored, finer-grained sandy silt zone several feet in thickness overlies bedrock at the location of dewatering well #1.

C. Shaft Log

A description of the earth materials and conditions encountered during the shaft ecavation is presented below. A lithologic sketch log of the shaft wall was attempted, but was only feasible in a few locations where undisturbed earth materials were exposed. Commonly, the method of shaft advancement and casing protection obscured the vertical shaft walls for sketching or photographic purposes.

Descriptions of the materials excavated were based on examination at the surface of materials recovered by the flight auger or bucket auger. by direct inspection of the in-situ materials as conditions permitted within the bottom of the shaft, and of materials at the different sampling internal depths. The descriptions are of conditions as estimated in the field. The various percentages of grain sizes given are based on visual volume estimates, not weight, and are therefore likely to vary from the grain size gradations (percentage based on weight) determined by the sieve analyses of samples

IV DENSITY TEST RESULTS

The following data sheets provide data for each of the eight density samples. Included are volume, weight, moisture and size gradation data.

As shown, the dry density calculations for both the one fill sample and the alluvium samples reveal a consistent increase in density with depth.

The percentage of sampled material passing the ¼-inch sieve screen ranges from a low of 31.3% for sample #4 to a high of 87.8% for sample #2 (just below the fill contact).

Both samples #4 and #8 were excavated with ground water seeping into the cavity, thus migration of fines into or out of the cavity may have occurred to a minor extent. It is estimated the weights of the ¼-inch size fraction for these samples may be in error up to 5%, plus or minus. In addition, the seepage water in the sample cavity reduced the efficiency of the rubber membrane to conform to the cavity walls, and the resultant volumes calculated for samples #4 and #8 are estimated to be 1.5% to 3.0% less than the actual volume of sediments excavated.

SUMMARY OF DENSITY TEST RESULTS

Test No.	Depth (ft)	Wet Density (PCF)	Moisture Content (%)	Dry Density (PCF)	Dry Sample Wt (Lbs)[1]
1	13.7	131.6	26.7	103.9	693.8
2	40.1	111.1	24.2	89.5	551.9
3	44.2	112.0	16.8	95.9	719.8
4	50.8	143.4	13.4	126.5	618.3
5	56.2	139.4	10.9	125.7	813.4
5			2.2	126.1	815.7 [2]
6	59.5	134.3	6.2	126.5	869.9
7	63.4	139.6	5.5	132.3	858.6
8	66.4	157.6	13.7	138.6	795.9
8			1.5	139.2	799.0 [2]

1. Calculated by: $\dfrac{\text{Wet Or Air Dry Weight}}{1 + \text{Moisture Content}}$

2. Dry weight recalculated from air dry weight and air dry moisture content to minimize error from very wet sample.

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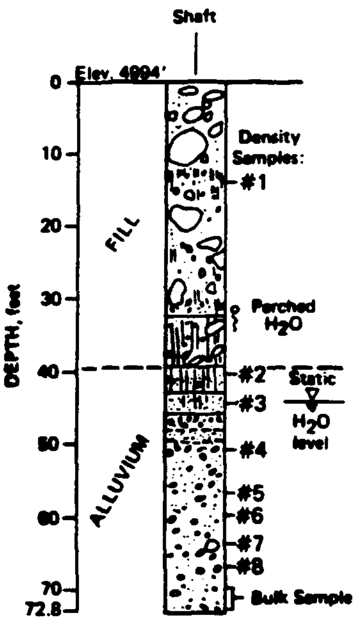

0-32.3'	**FILL** Silt, Sand, Gravel, Boulders: variable %; moist to locally saturated; boulders to 5' size; typically Silty Sand to Sandy Gravel.
32.3-39.6'	Gravelly silt: low to non-plastic fines; very dense; chaotic rounded gravel and scattered boulders, approx. 15-25%; broken roots common.
	ALLUVIUM
39.6–43'	Sand and Silt: weakly stratified; very fine sand; low plasticity fines; fine to coarse gravel and boulders to 1', less than 3%; moist; medium dense.
~43'-45.7'	Silty Sand: non-plastic fines 20-50%; very fine sand; medium dense; moist; shell fragments within.
45.7'-72.8'	Sand and Gravel: non-plastic fines 5-15%; fine- to coarse-grained sand, 10-50%; gravel to 3-4", typically ½-1"; well rounded medium dense to dense silt and sand lenses observed, 48-50'.

Earth Sciences Associates
Palo Alto, California

RIRIE DAM TEST SHAFT
SUMMARY FIELD LOG OF TEST SHAFT

Checked by ________ Date ______	Project No.	Figure No.
Approved by ________ Date ______	[illegible]	5

FIELD DESCRIPTION OF DENSITY SAMPLES

Sample No.	Depth Below Sfc. (feet)	Field Description
		FILL
1	13.7-15±	SILTY GRAVEL; reddish to brownish gray, low plasticity fines estimated at 35%; fine to coarse sand, predominately coarse, estimated at around 30%; angular gravel and boulders to 3 feet estimated 35%; moist.
		ALLUVIUM
2	40.1-42.6	SILT; (silty clay to very fine-grained sand); low plasticity fines; very fine sandy clay, silt, very fine sand, weakly stratified in thin lenses 1/2- to 3-inches thick. Fine to coarse gravel and boulders to 1 foot, less than 3%, in poorly defined zones, no apparent stratification, chaotic. Firm to stiff silty clay, Pocket Penetrometer (PP) approximately 2.1 tons/ft^2 minimum to 4.5 tons/ft^2 in medium dense sandy silt-silty sand; moist.
3	44.2-47	SILTY SAND; non-plastic fines, estimated 20-50%; very fine sand; pebbles less than 2%; medium dense; uniform; a few roots, less than 1%; white shell fragments within; moist.
	45.7-47±	SILTY GRAVEL; low to non-plastic fines, 5-15%; fine to coarse-grained sand 10-50%; gravel to 4 inches, typically 1/2-to 1-inch, typically well rounded; abundant sedimentary and metasedimentary clasts (shale, quartzite, quartz, siliceous and limey shale), minor volcanics; loose-medium dense; moist; sharp contact at 45.7 feet.
4	50.8-52.5	GRAVELLY SAND; fine to coarse sand 50+%; well graded gravel, well rounded and flattened clasts; loose-medium dense; saturated.
5	56.2-58.0	GRAVELLY SAND (SANDY GRAVEL); slightly plastic fines 5-12%; medium dense; well graded fine-to-coarse-grained sand and gravel; sub-angular to well-rounded clasts, elongated commonly; wet to very wet (resembles wet cement, dark gray); weakly developed lense of sandy silt, around 2 inches thick, discontinuous at around 57.3 feet.
6	59.5-61.3	GRAVELLY SAND (SANDY GRAVEL); slightly plastic fines less than 8%; loose to medium dense; wet; moderately graded; sub-angular to typically well rounded clasts; flat, elongated common; drier than #5; local wall section reveals chaotic to locally weakly, crudely stratified. 30-inch boulder at 58.6 feet hangs up 7 feet casing; also 12- to 18-inch boulder wedged against casing; saturated locally at margin of 30-inch boulder.

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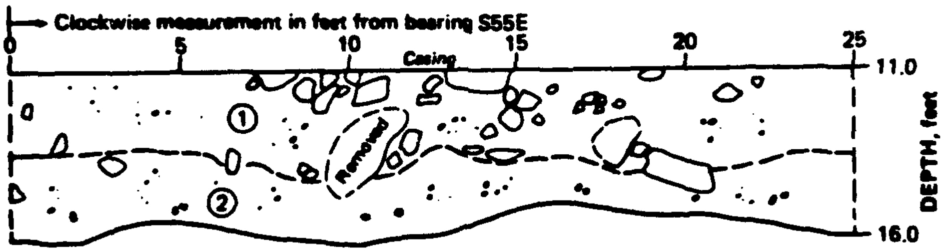
7	63.4-65.2	GRAVELLY SAND (SANDY GRAVEL); Same as #6; slightly wetter than #6; no boulders; no distinct bedding or lenses; locally clean fine to coarse sand and fine gravel zone at around 63.4- 63.6-feet, very gradational.
8	66.4-67.8	GRAVELLY SAND (SANDY GRAVEL); Fines less than 10%; medium dense; well rounded; flattened clasts common; no distinct stratafication; wall exposure limited, displays imbricate structure of flat clasts, poorly developed; also chaotic zones.
	66.4-	Wet-saturated; seepage invades from upstream (dam) direction.

Geologic Log of Shaft

DEPTH	DESCRIPTION
	FILL
0-3'	SILTY GRAVEL: brown (7.5 YR 4/2); non- to slightly plastic fines 30 - 50%; fine- to coarse-grained sand, 20 - 35%; angular gravel, cobbles, boulders to 3' size, 30 - 50%; loose - dense; chaotic; moist.
3'	Yellowish band approx. 1' thick, horizontal.
6'	5' boulder; numerous others less than 5'.
6-12'	SANDY SILT: low plasticity fines 30 - 50%; sand, 30 - 40%; gravel (¼" - 3") 15 - 30%; cobbles and boulders 15 - 25%.
12'-	SILTY SAND: low plasticity fines approx. 30%; sand approx. 30%; gravel to 3" 15 - 25%; cobbles-boulders 15 - 25%.

WALL LOG 11.0'-16.0'

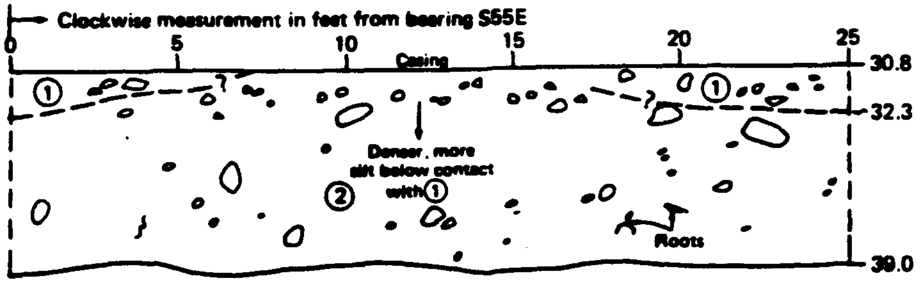


① SILTY GRAVEL: brownish gray; low plasticity fines approx. 35%; coarse sand (predom.) 30%; angular gravel and boulders to 3 feet, remainder; moist.

② SILTY SAND: pale reddish gray; low plasticity fines approx. 40%; fine to coarse sand approx. 40%; angular gravel approx. 20%; cobbles, boulders less than 5%; moist.

18-21'	Locally reddish brown (5 YR 4/4); locally wet; silty clay fines are slightly plastic; abundant boulders to 4' size.
21-29'	Boulders typically less than 4'.
29'	Reddish gray color typically; locally perched water, saturated zones. Boulders 4½' to 5' maximum size.
30'	Color grades to gray-brown, less large boulders, more sand; locally wet-saturated.

WALL LOG 30.8'-37.0'

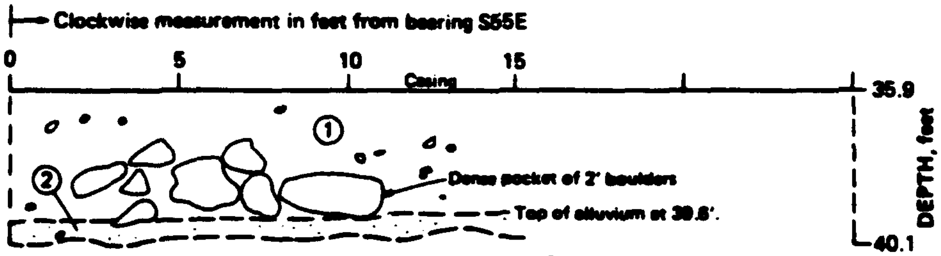


① SILTY GRAVEL: low to non-plastic fines 30-50%; sand approx. 30%; gravel 30-80%; massive, chaotic; angular fragments predominate; med. dense-dense; moist-wet; local seepage, perched above unit ②.

② GRAVELLY SILT; dark gray brown (10 YR 4/2) ; low to non-plastic fines 60 to 80%; sand 5 to 20%; gravel 15 to 25%, chaotic, predominantly well rounded; scattered boulders, damp to damp-moist; very dense; organic fibers, broken roots present.

DEPTH	DESCRIPTION
39.6'- ~43'	Alluvium SANDY SILT: low plasticity clayey fines with very fine sand, and silt in weakly stratified thin lenses, ½ to 3" in thickness; gravel and boulders less than 3%; boulders to 1'; gravel is fine to coarse; unstratified; roots common near contact; sandy silt is medium dense, silty clay is firm to stiff; moist.

WALL LOG 35.9'-40.1'

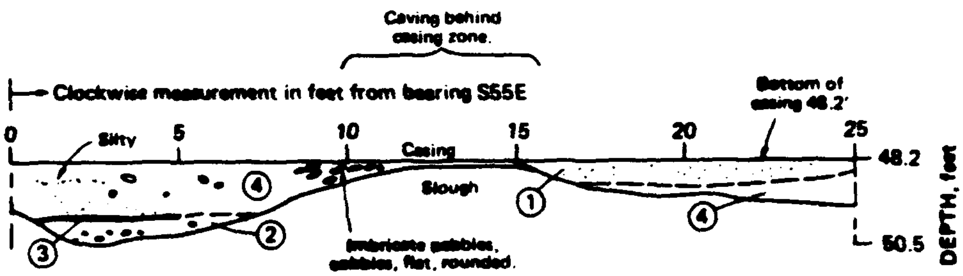


① GRAVELLY SILT (same as unit 2 above wall log, 32.3-39.6).

② SANDY SILT: ALLUVIUM (same as above 39.6-43').

~43-45.7'	SILTY SAND: non-plastic fines approx. 20 - 50%; very fine sand; white shell fragments within; medium dense; moist; homogeneous, uniform; a few roots, less than .1%, pebbles less than 2%.
45.7-47'	SILTY GRAVEL: low - non-plastic fines fines 5 - 15% ; fine - to coarse-grained sand approx. 10 - 50%; gravel to 3" - 4", typically approx. ½ - 1"; commonly well rounded, non-basaltic; shale, quartzite, limestone, chert (?); moist; medium-dense to loose; short contact with overlying silty sand.

WALL LOG 48.2'-50.5'±



① SAND: fine- to coarse-grained; moderately well graded; shell-rich; loose to medium dense; no fines.

② SILTY SAND AND GRAVEL: low plasticity fines variable %, typically <20%; fine to coarse sand approx. 70%; fine to medium gravel; medium dense; moist.

③ Clean silt lense: pocket penetrometer = 1.1-1.75 TSF, moist.

④ SILTY SAND, SANDY GRAVEL, interlensed; poorly defined lenses, gradational; loose fine gravel - coarse sand; rounded clasts; loose pea-gravel locally; shell-rich.

DEPTH	DESCRIPTION
50.5-66.8'+	GRAVELLY SAND - SANDY GRAVEL: dark gray; slightly plastic fines typically 5 to 15%; medium dense; well graded sand and gravel; subangular to well-rounded clasts, elongated and flattened commonly; wet; typically massive, local weak imbricate structure; resembles wet cement.
66.8-72.8'	SANDY GRAVEL: massive; very dense; saturated; well-rounded to flattened clasts; 1" to 3" clast size estimated 50+%; weak imbricate alignment of cobbles locally.

Photo 1. Drilling dewatering well #3A with air-rotary equipment. Pneumatic hammer above discharge hose (orange box) drives casing down as drilling advances. Discharge is erratic, eruptive, through casing and hose.

Photo 2. Assembly of Johnson well screen during installation of dewatering well #33.

Photo 3. 7 foot diameter flight auger on trip out of shaft.

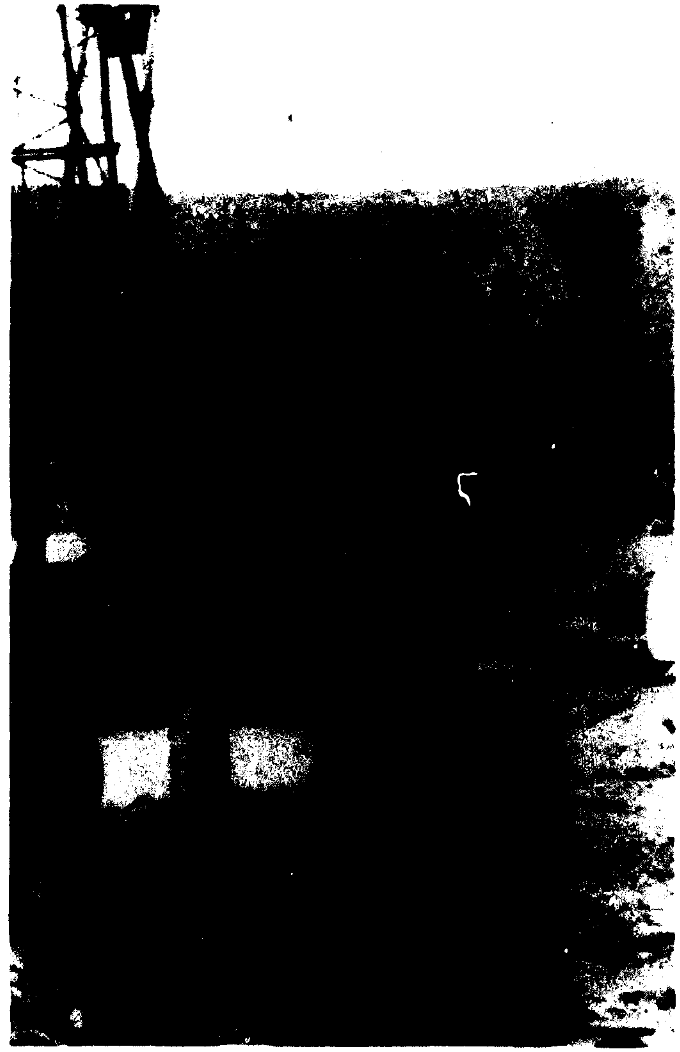


Photo 4. Steel man-cage entering top of shaft; yellow ventilation hose in foreground.

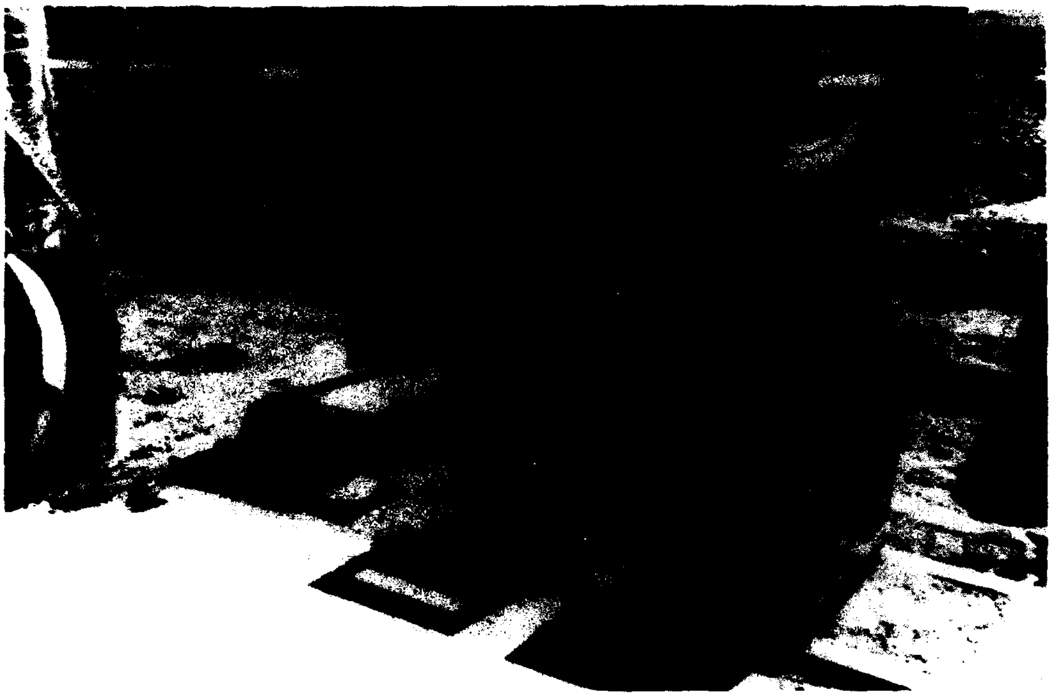


Photo 5. Gilson shakers for sieve analysis adjacent to scale. Sample ring and bucket at left.

Photo 6. Assembly of drying box and space heater to aid air drying process of samples.

Photo 7. Checking moisture condition of sample #8 during air drying process in dryer box; removable covers in background.

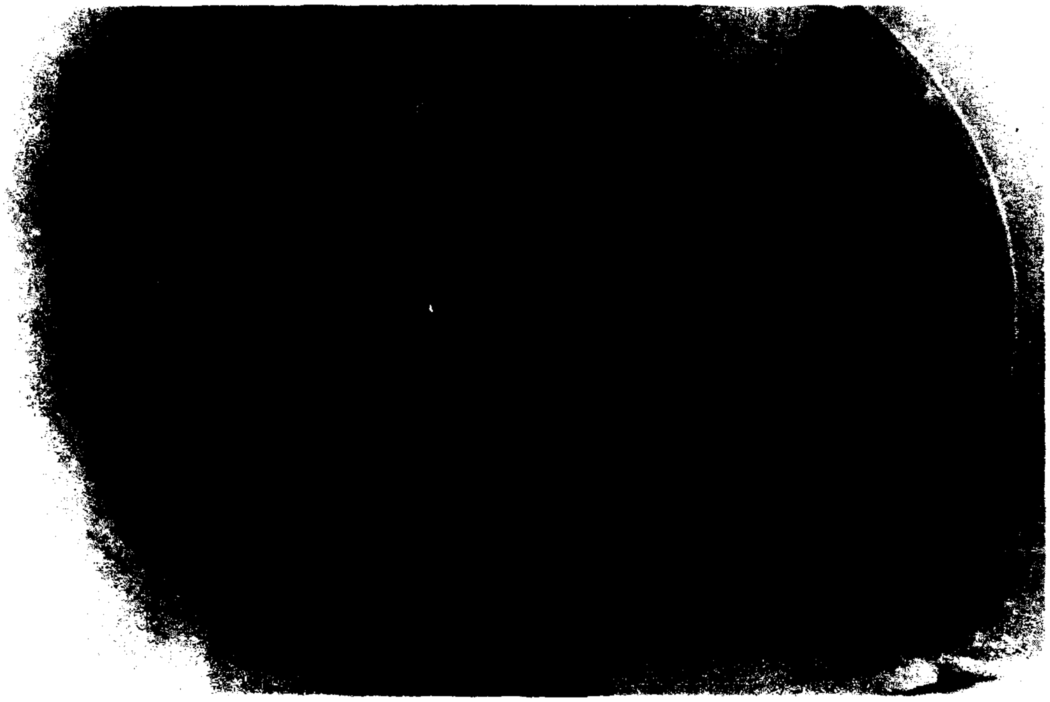


Photo 8. Sample #1, prior to membrane placement, fill material caves readily behind 8' diameter steel casing.

Photo 9. Sample #1, placing membrane on ring.

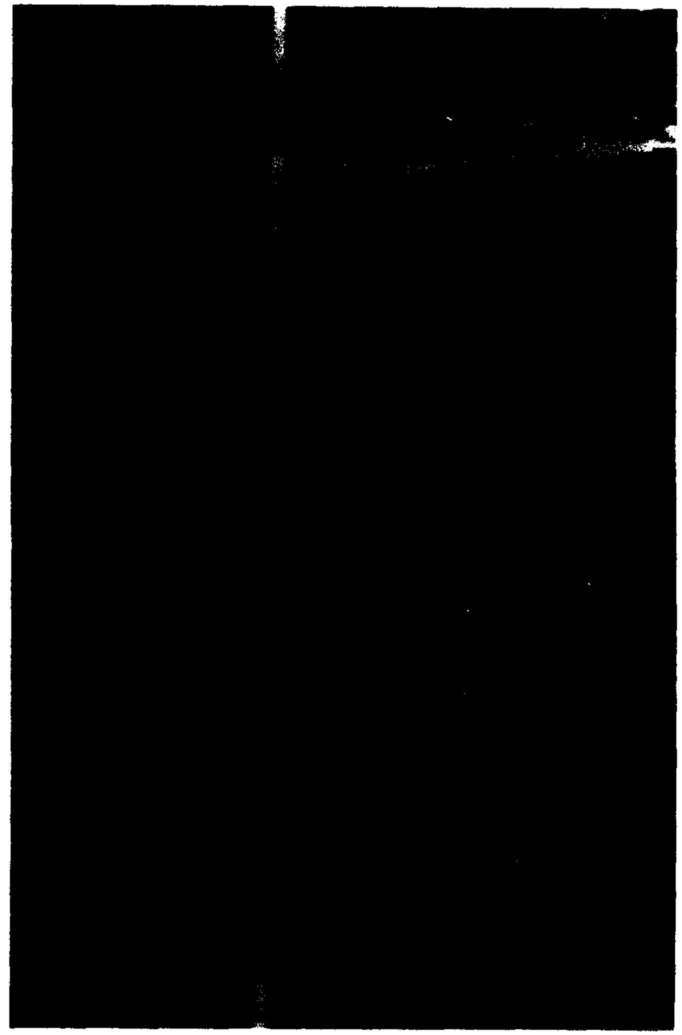


Photo 10. Detail of shaft wall below bottom of casing @ 30.8'. Approximate contact of coarser over finer-grained fill material exists near center of pick handle; obscure in photos. View approx. S55E.

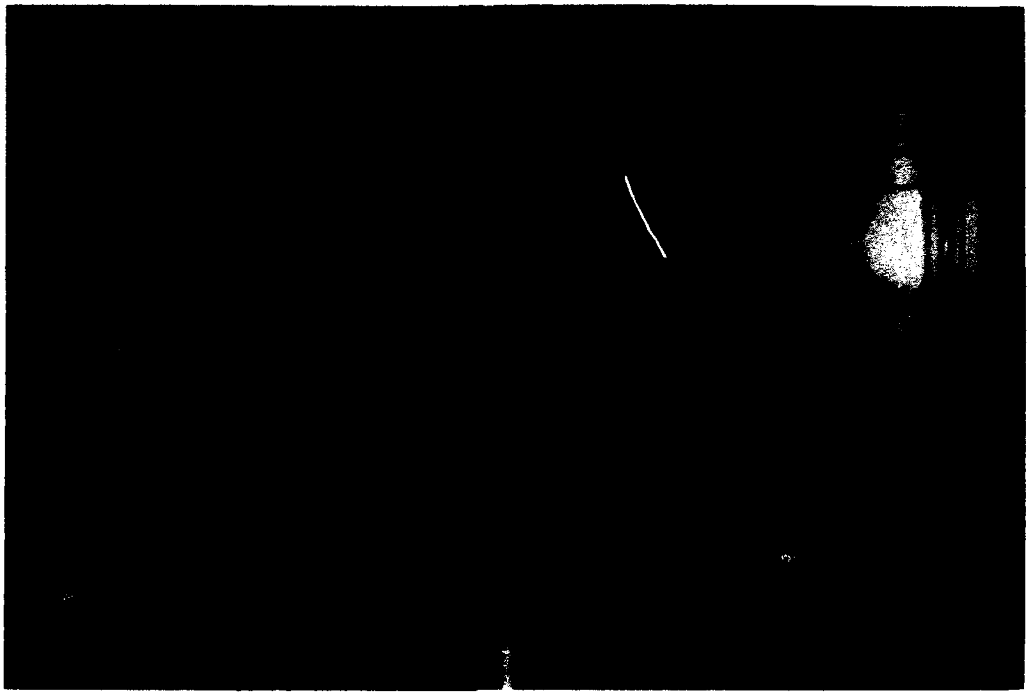


Photo 11. Shaft wall below 30.8'.

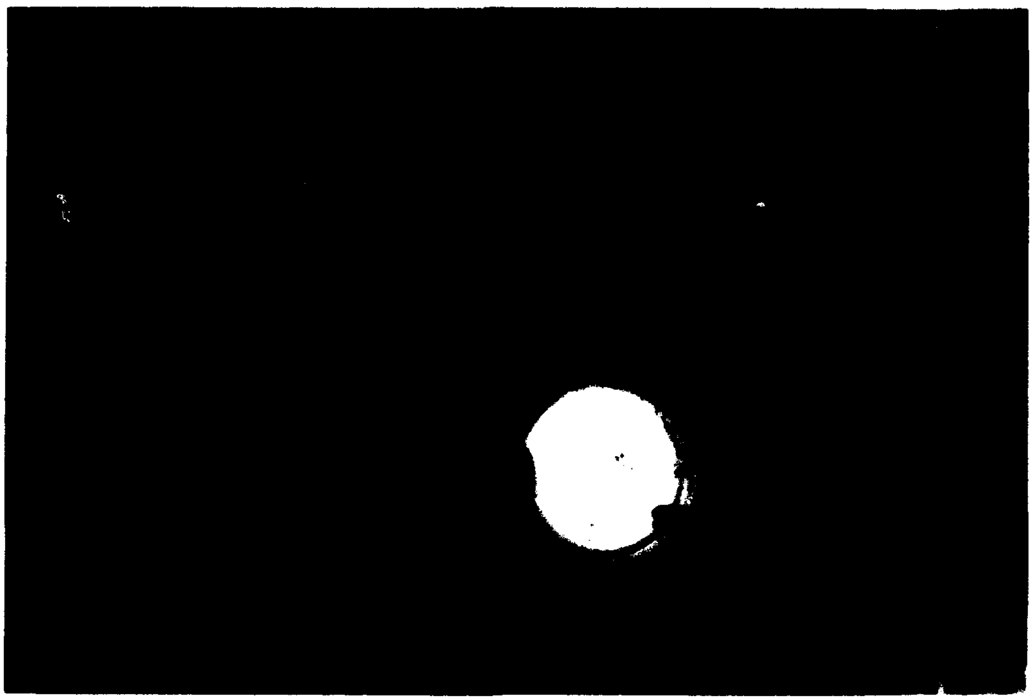


Photo 12. View upwards @ 63' level. Safety equipment includes rope ladder, safety lines, air blower, and steel cage.

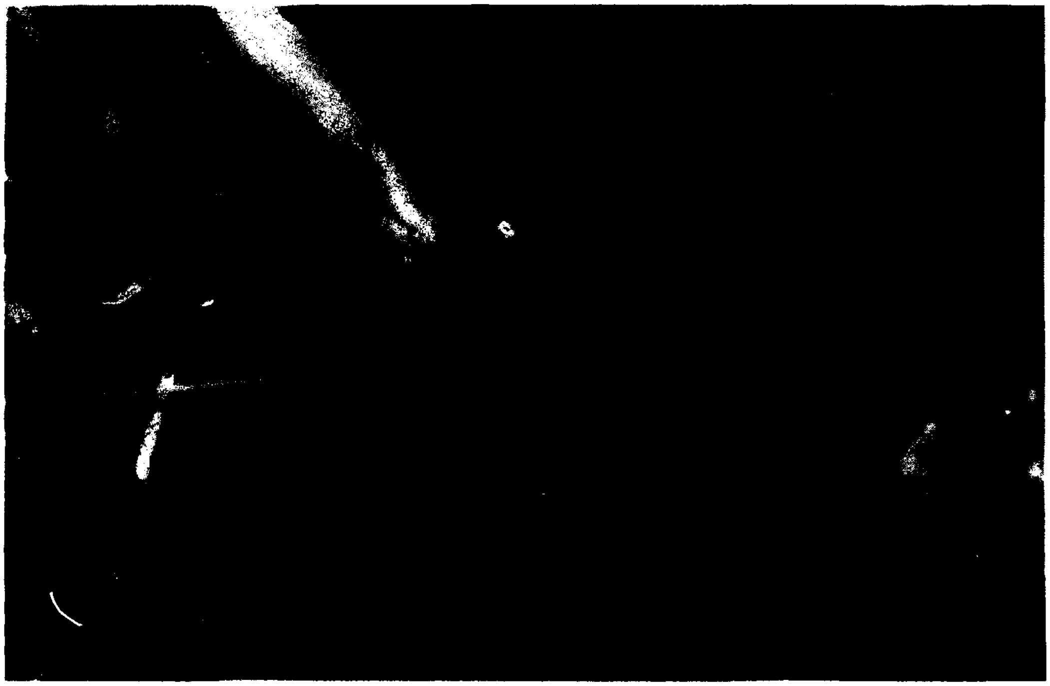


Photo 13. Evacuating water-filled membrane in cavity of sample #7 at 63.4 feet; electric pump discharges water into steel bucket, then it is hoisted out. Conformity of membrane to gravel wall illustrated.

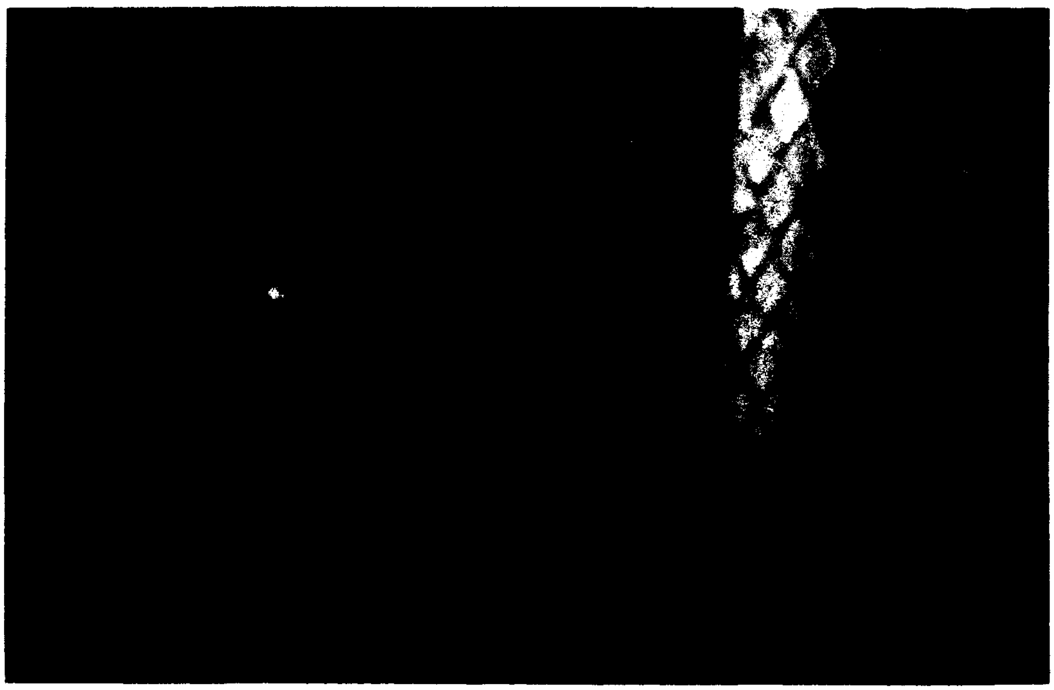


Photo 14. Detail of sand and gravel deposits below bottom of casing at 66.8'; Deposits are dense, massive here, with slight imbrication of clasts evident; abundant water seepage over wall surface. (1 of 3)

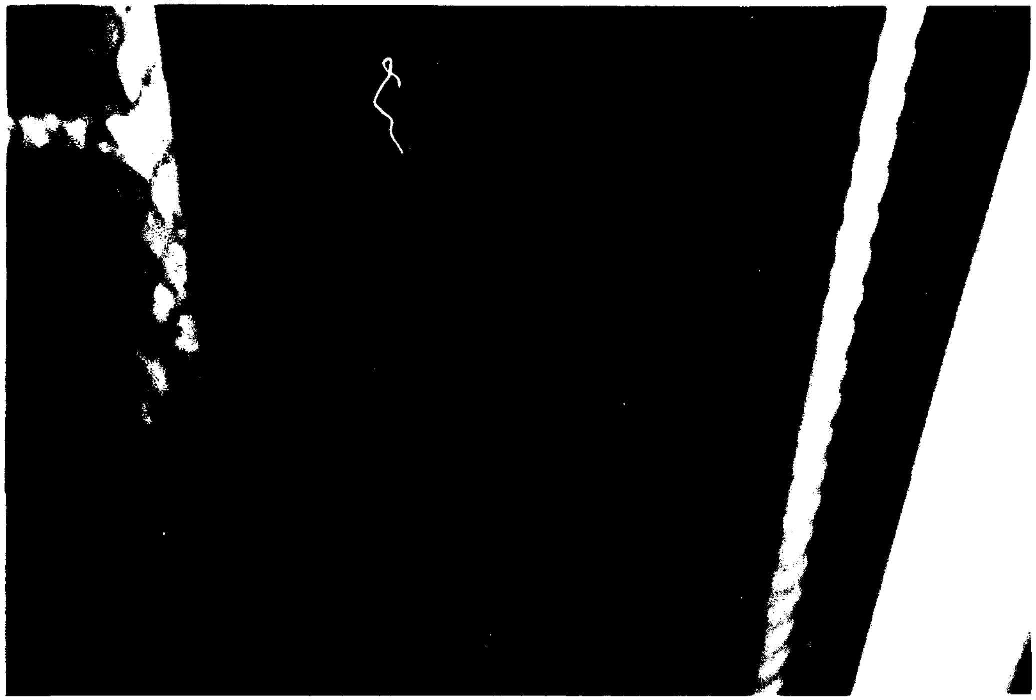


Photo 15. Below bottom of casing @ 66.8'. (2 of 3)

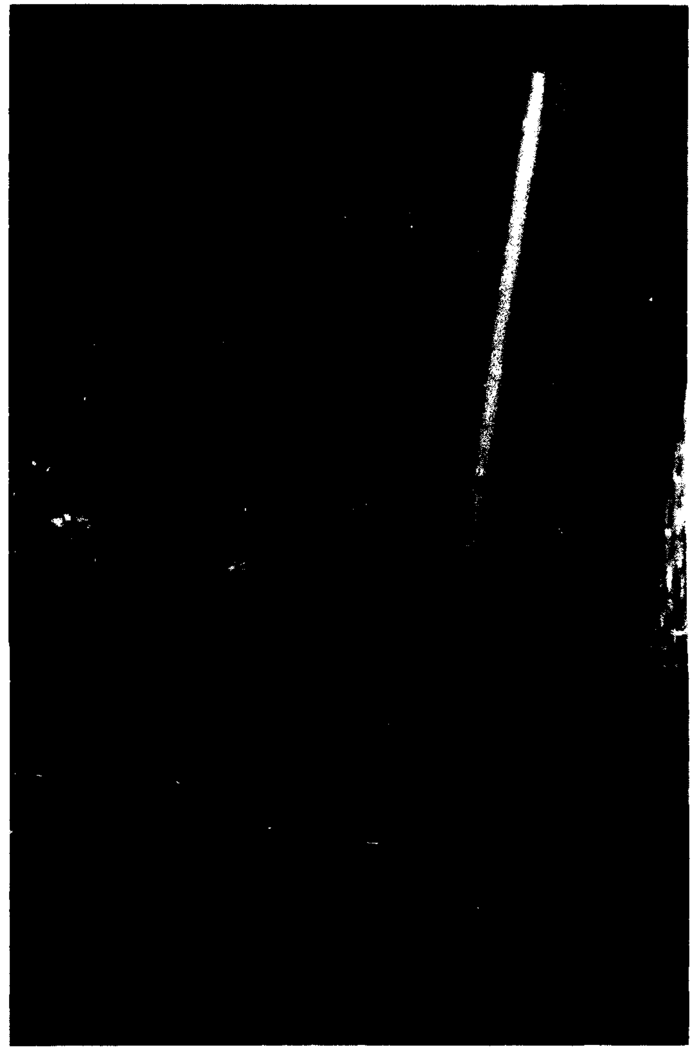


Photo 16. Below bottom of casing @ 66.8'. (3 of 3)

Photo 17. 10 foot-long perforated casing for sump pump in place at bottom of shaft (70.3); PVC discharge pipe extends to surface; saturated massive sand and gravel deposits apparent. (1 of 2)

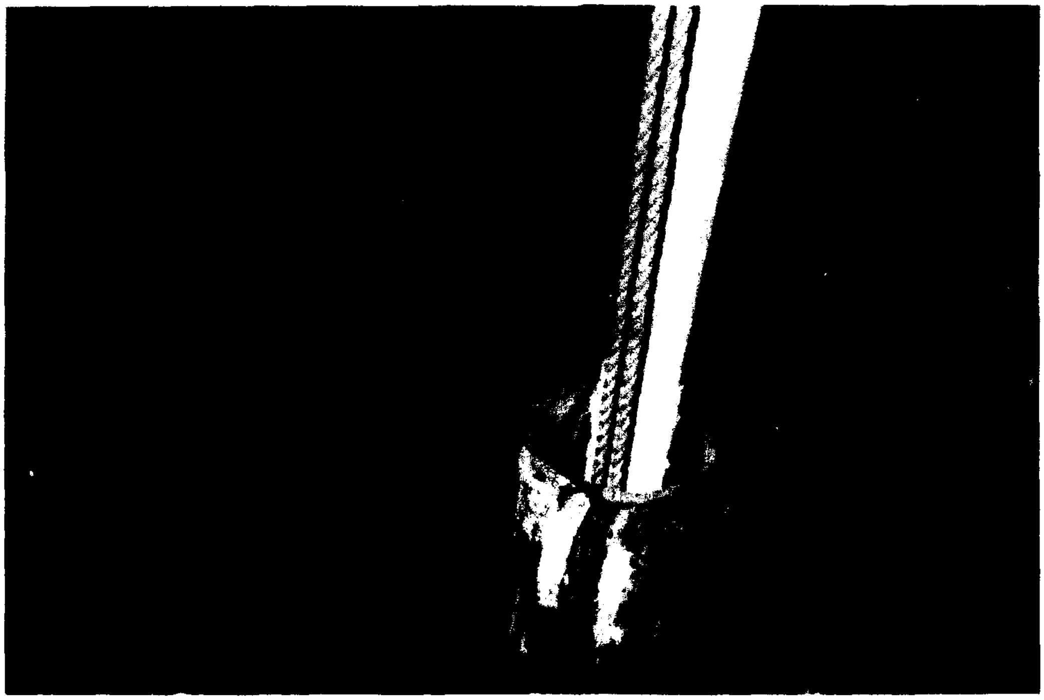


Photo 18. Sump pump casing and massive sand and gravel deposits at approx. 70' depth. (2 of 2)

Test No.: 1

Depth: 13.7'

Date: 8/8/84

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By: JSH

Comments:

Hole Volume

	Meter 1	Meter 2	Avg.	Vol. (Gal.)		Vol (ft.³)
Initial	98.70	129.05				
1st Read	121.05	151.55	______			
Δ	22.35	22.50	22.43			
Initial (2)	121.05	151.55				
2nd Read	193.35	224.05	______			
Δ	72.30	72.50	72.40	= 49.97	÷ 7.48 =	6.68 ft.³

Gross Weight (wet)

	No. 1		No. 2		Total	Density (wet)
Soil + Bucket	730.5		821.5			
Bucket	− 336.5		− 336.5			
Soil	394.0	+	485.0	=	879.0	131.6 lbs./ft.³

Moisture

Weight (Wet + Tare)	23.50	
Weight (Dry + Tare)	19.00	
Weight Water	4.50	
Tare Weight	2.13	
Weight Soil (Dry)	16.87	Density (dry)
% Moisture Content	26.7	103.9 lbs./ft.³

Gradation

Sample AIR Dry Weight = 821.25 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	57.55	57.55	763.70	93.0
3"	54.80	112.35	708.90	86.3
1½"	137.60	249.95	571.30	69.6
¾"	145.60	395.55	425.70	51.8
⅜"	68.05	463.60	357.65	43.5
# 4	120.55	584.15	237.10	28.9
Pan	237.10	821.25	–	–

Earth Sciences Associates

Test No.: 2

Depth: 40.1' (FLANGE)

Date: 8/17/84

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By: JSH

Comments:

Hole Volume

	Meter 1	Meter 2	Avg.	Vol. (Gal.)	Vol ($ft.^3$)
Initial	230.90	200.55			
1st Read	251.95	221.55			
Δ	21.05	21.00	21.03		
Initial (2)	254.50	224.05			
2nd Read	321.85	291.05			
Δ	67.35	67.00	67.18	= 46.15 ÷ 7.48 =	6.17 $ft.^3$

Gross Weight (wet)

	No. 1		No. 2		Total	Density (wet)
Soil + Bucket	682.5		673.0			
Bucket	− 335.0		− 335.0			
Soil	347.5	+	338.0	=	655.5	111.1 $lbs./ft.^3$

Moisture

Weight (Wet + Tare)	23.70	
Weight (Dry + Tare)	19.50	
Weight Water	4.20	
Tare Weight	2.13	
Weight Soil (Dry)	17.37	Density (dry)
% Moisture Content	24.2	89.5 $lbs./ft.^3$

Gradation

Sample AIR Dry Weight = 543.6 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	—	—	543.6	100%
3"	2.0	2.0	541.6	99.6
1½"	7.9	9.9	533.7	98.2
¾"	10.8	20.7	522.9	96.2
⅜"	9.5	30.2	513.4	94.4
#4	36.2	66.4	477.2	87.8
Pan	477.2	543.6	—	—

Test No.: 3

Depth: 44.2'

Date: 8/18/84

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By: TDH

Comments:

Hole Volume

	Meter 1	Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial	326.15	295.40			
1st Read	350.05	319.20			
Δ	23.90	23.80	23.85		
Initial (2)	350.10	319.20			
2nd Read	422.75	391.75			
Δ	72.65	72.55	72.60		

WATER LEVEL FOR 2ND READING STOPPED $1^3/4$" = 0.1458' BELOW MARK OF INITIAL READING (RING = 2.94' ID)

$\Delta V = \frac{\pi D^2}{4} \times \Delta H$

$\Delta V = 0.99$ cf

THEN 72.60 − 23.85 = 48.75

48.75 ÷ 7.48 = 6.52 cf

+0.99 cf

7.51

CORRECTED VOL

= ______ ÷ 7.48 = 7.51 ft.^{3}

Gross Weight (wet)

	No. 1	No. 2	Total	Density (wet)
Soil + Bucket	879.25	631.5		
Bucket	− 335.00	− 335.0		
Soil	544.25 +	296.5 =	840.75	11[illegible].0 lbs./ft.^{3}

Moisture

Weight (Wet + Tare)	23.0
Weight (Dry + Tare)	20.0
Weight Water	3.0
Tare Weight	2.13
Weight Soil (Dry)	17.87
% Moisture Content	16.8

Density (dry) 95.9 lbs./ft.^{3}

Gradation

Sample AIR Dry Weight = 704.9 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	–	–	–	–
3"	–	–	704.9	100%
1½"	12.1	12.1	692.8	98.3
¾"	41.7	53.8	651.1	92.4
⅜"	31.1	84.9	620.0	88.0
#4	64.3	149.2	555.7	78.9
Pan	555.7	704.9	–	–

Earth Sciences Associates

Test No.: 4

Depth: 50.6'

Date: 8/30/84

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By:

Comments: SAMPLE TAKEN FROM STANDING WATER

Hole Volume

	02 Meter 1	03 Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial	426.45	395.55			
1st Read	444.75	413.65			
Δ	18.30	18.10	18.20		
Initial (2)	444.75	413.65			
2nd Read	499.45	465.45			
Δ	54.70	54.80	54.75	= 36.55 ÷ 7.48	= 4.89 ft^3

Gross Weight (wet)

	No. 1		No. 2		Total	Density (wet)
Soil + Bucket	989.5					
Bucket	− 314.5		−			
Soil	675.0	+	26.1	=	701.1	143.4 lbs./ft.^{3}

Moisture

Weight (Wet + Tare)	30.0
Weight (Dry + Tare)	26.7
Weight Water	3.30
Tare Weight	2.13
Weight Soil (Dry)	24.57
% Moisture Content	13.4

Density (dry)

126.43 lbs./ft.^{3}

Gradation

Sample AIR Dry Weight = 608.9 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	–	–	–	–
3"	–	–	608.9	100%
1½"	45.9	45.9	563.0	92.5
¾"	131.2	177.1	431.8	70.9
⅜"	73.1	250.2	358.7	58.9
#4	168.2	418.4	190.5	31.3
Pan	190.5	608.9	–	–

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Test No.: 5

Depth: 56.2'-58.0'

Date: 8/2/85

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By: PVJ

Comments: p. 1 of 2

Hole Volume

	#603 Meter 1	#602 Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial	504.85	536.40			
1st Read	525.90	557.70			
Δ	21.05	21.30	21.18		
Initial (2)	526.45	558.20			
2nd Read	595.70	62[illegible]			
Δ	69.25	69.[illegible]	69.55	= 48.37 ÷ 7.48 =	6.47 ft.^{3}

Gross Weight (wet)

	No. 1	No. 2	Total	Density (wet)
Soil + Bucket	740.75	789.75		
Bucket	− 314.20	− 314.20		
Soil	426.55 +	475.55 =	902.10	139.4 lbs./ft.^{3}

Moisture

	PAN #1	PAN #2	PAN #3	
Weight (Wet + Tare)	13.20 lbs	13.68 lbs	12.55 lbs	
Weight (Dry + Tare)	11.99	12.38	11.38	Av % Moisture Content:
Weight Water	1.21	1.30	1.17	10.9%
Tare Weight	0.69	0.71	0.69	
Weight Soil (Dry)	11.30	11.67	10.69	Density (dry)
% Moisture Content	10.7	11.1	10.9	125.7 lbs./ft.^{3}

Gradation

Sample ½ Dry Weight = 833.61

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	0 lbs	0 lbs	831.63	100 %
3"	18.83	18.83	812.80	97.7
1½"	107.58	126.41	705.22	84.8
¾"	140.66	267.07	564.56	67.9
⅜"	70.58	337.65	493.98	59.4
#4	134.16	471.81	359.82	43.3
Pan	359.82	831.63	—	—

Earth Sciences Associates

Test No.: 5

Depth: 56.2' - 58.0'

Date: 8/2/85

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By: PVJ

Comments: P2 OF 2

AIR-DRIED SOIL MOISTURE CONTENT & CORRECTED AIR-DRY WEIGHT

Hole Volume

	Meter 1	Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial					
1st Read					
Δ					
Initial (2)					
2nd Read					
Δ				= ÷ 7.48 =	6.47 ft.^{3}

Gross Weight (wet)

	No. 1	No. 2	Total	Density (wet)
Soil + Bucket				
Bucket	−	−		
Soil		+	= 833.61	128.8 lbs./ft.^{3}

Moisture

	PAN # 1	PAN # 2	PAN # 3	
Weight (Wet + Tare)	9.48 lbs	9.18 lbs	10.43 lbs	
Weight (Dry + Tare)	9.31	9.01	10.18	AV % MOISTURE CONTENT
Weight Water	0.17	0.17	0.25	2.2 %
Tare Weight	0.69	0.71	0.69	
Weight Soil (Dry)	8.62	8.30	9.49	Density (dry)
% Moisture Content	2.0	2.0	2.6	126.1 lbs./ft.^{3}

Gradation

Sample Dry Weight

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"				
3"				
1½"				
¾"				
⅜"				
# 4				
Pan				

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Test No.: 6

Depth: 59.5'-61.3'

Date: 8/5/85

By: PVJ

Comments:

3 FOOT SAMPLING DENSITY AND SIEVE TEST

Hole Volume

	#602 Meter 1	# 603 Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial	650.00	617.20			
1st Read	668.85	635.65			
Δ	18.85	18.45	18.65		
Initial (2)	668.30	636.30			
2nd Read	738.55	706.30			
Δ	70.25	70.00	70.13	= 51.48 ÷ 7.48	= 6.88 ft.^{3}

Gross Weight (wet)

	No. 1	No. 2	Total	Density (wet)
Soil + Bucket	772.2	780.0		
Bucket	− 314.2	− 314.2		
Soil	458.0 +	465.8 =	923.8	134.3 lbs./ft.^{3}

Moisture

	PAN # 1	PAN # 2	PAN # 3	
Weight (Wet + Tare)	7.33 lbs	7.52 lbs	7.03 lbs	
Weight (Dry + Tare)	6.92	7.17	6.64	
Weight Water	0.41	0.35	0.39	AV % MOISTURE CONTENT
Tare Weight	0.69	0.71	0.69	6.2%
Weight Soil (Dry)	6.23	6.46	5.95	Density (dry)
% Moisture Content	6.6%	5.4%	6.6%	126.5 lbs./ft.^{3}

Gradation

Sample AIR Dry Weight = 883.74 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	0 lbs	0 lbs	883.74 lbs	100%
3"	31.09	31.09	852.65	96.5
1½"	153.68	184.77	698.97	79.1
¾"	162.93	347.70	536.04	60.7
⅜"	79.34	427.04	456.70	51.7
# 4	154.93	581.97	301.77	34.1
Pan	301.77	883.74	—	—

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Test No.: 7

Depth: 63.4' - 65.1'

Date: 8/6/85

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By: PVJ

Comments:

Hole Volume

	#602 Meter 1	#603 Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial	749.60	714.45			
1st Read	769.30	734.15			
Δ	19.70	19.70	19.70		
Initial (2)	770.40	735.15			
2nd Read	838.55	802.45			
Δ	68.15	68.30	68.23	= 48.53 ÷ 7.48 =	6.49 ft.^{3}

Gross Weight (wet)

	No. 1		No. 2		Total	Density (wet)
Soil + Bucket	779.50 lbs		754.75 lbs			
Bucket	− 314.20		− 314.20			
Soil	465.3	+	440.55	=	905.85	139.6 lbs./ft.^{3}

Moisture

	PAN # 1	PAN # 2	PAN # 3	
Weight (Wet + Tare)	8.84 lbs	9.28 lbs	9.15 lbs	
Weight (Dry + Tare)	8.48	8.76	8.71	AV. % MOIST. CONTENT
Weight Water	0.36	0.52	0.44	5.5 %
Tare Weight	0.69	0.71	0.69	
Weight Soil (Dry)	7.79	8.05	8.02	Density (dry)
% Moisture Content	4.6	6.5	5.5	132.3 lbs./ft.^{3}

Gradation

Sample Air Dry Weight = 863.18 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	0 lbs	0 lbs	863.18 lbs	100 %
3"	9.33	9.33	853.85	98.9
1½"	155.56	164.89	698.29	80.9
¾"	177.16	342.05	521.13	60.4
⅜"	78.73	420.78	442.40	51.3
# 4	131.91	552.69	310.49	36.0
Pan	310.49	863.18	–	–

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Test No.: 6

Depth: 66.4' - 67.8'

Date: 8/7/85

3 FOOT SAMPLING DENSITY AND SIEVE TEST

By:

Comments: #1 OF 2
SAMPLE SATURATED
MEMBRANE VOLUME REDUCED
[illegible] WATER IN SAMPLE HOLE

Hole Volume

	#602 Meter 1	#609 Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial	841.55	806.35			
1st Read	857.20	822.00			
Δ	15.65	15.65	15.65		
Initial (2)	858.15	822.95			
2nd Read	916.70	881.50			
Δ	58.55	58.55	58.55	= 42.9 ÷ 7.48	= 5.74 ft.^{3}

Gross Weight (wet)

	No. 1	No. 2	Total	Density (wet)
Soil + Bucket	786.2 lbs	745.1 lbs		
Bucket	− 314.2	− 314.2		
Soil	374.0 +	430.9 =	904.9	157.6 lbs./ft.^{3}

Moisture

	PAN #1	PAN #2	PAN #3	
Weight (Wet + Tare)	12.19 lbs	9.77 lbs	11.36 lbs	
Weight (Dry + Tare)	10.77	8.61	10.23	AV % MOISTURE CONTENT
Weight Water	1.42	1.61	1.13	13.7 %
Tare Weight	0.69	0.71	0.69	
Weight Soil (Dry)	10.08	7.90	9.10	Density (dry)
% Moisture Content	14.1	14.7	12.4	135.6 lbs./ft.^{3}

Gradation

Sample Air Dry Weight 809.93 lbs

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"	0 lbs	0 lbs	809.93 lbs	100 %
3"	44.93	44.93	765.00	94.5
1½"	95.53	140.46	669.49	82.7
¾"	138.06	278.52	531.41	65.6
⅜"	73.33	351.85	458.08	56.6
#4	134.66	486.51	323.42	39.9
Pan	323.42	809.93	—	—

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Test No.: 9

Depth: 66.4' - 67.8'

Date: 8/7/85

By:

Comments: p. 2 of 2

3 FOOT SAMPLING DENSITY AND SIEVE TEST

AIR-DRIED SOIL % MOISTURE CONTENT = CORRECTED AIR-DRY WEIGHT

Hole Volume

	Meter 1	Meter 2	Avg.	Vol. (Gal.)	Vol (ft.^{3})
Initial					
1st Read					
Δ					
Initial (2)					
2nd Read					
Δ				= ÷ 7.48 =	5.74 ft.^{3}

Gross Weight (wet)

	No. 1	No. 2	Total	Density (wet)
Soil + Bucket				
Bucket	−	−		
Soil	+		= 811.03	141.3 lbs./ft.^{3}

Moisture

	PAN #1	PAN #2	PAN #3	
Weight (Wet + Tare)	10.35 lbs	11.63	10.25	
Weight (Dry + Tare)	10.22	11.46	10.10	AV % MOISTURE CONTENT
Weight Water	0.13	0.17	0.15	1.5 %
Tare Weight	0.69	0.71	0.69	
Weight Soil (Dry)	9.53	10.75	9.41	Density (dry)
% Moisture Content	.4	1.6	1.6	139.2 lbs./ft.^{3}

Gradation

Sample Dry Weight

Sieve Size	Weight Retained	Accumulated Weight	Weight Passing	Percentage Passing
6"				
3"				
1½"				
¾"				
⅜"				
#4				
Pan				

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NOT REPRODUCED BECAUSE OF POOR QUALITY

APPENDIX

Photographs
Water Well Logs

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APPENDIX G: REPORT SUBMITTED BY EARTH TECHNOLOGY CORPORATION

(January 1985)

CONE PENETROMETER TESTING
RIRIE DAM
RIRIE, IDAHO

Prepared for:
U.S. ARMY CORPS OF ENGINEERS
Waterways Experiment Station
Vicksburg, Mississippi 39180

Prepared by:
THE EARTH TECHNOLOGY CORPORATION
3777 Long Beach Boulevard
Long Beach, California 90807

January, 1985
85-140-05

The Earth Technology Corporation

3777 Long Beach Boulevard · P.O. Box 7765 · Long Beach, California 90807
Telephone: (213) 595-6611 / (714) 821-7062 · Telex: 656338

January 29, 1985

Commander and Director
U.S. Army Engineers
Waterways Experiment Station, Corps of
Engineers
P.O. Box 631 - Halls Ferry Road
Vicksburg, MS 39180

Dear Sirs:

This bound report describes in detail The Earth Technology Corporation's Cone Penetrometer Test (CPT) investigation at Ririe Dam, Idaho, performed under terms of Purchase Order No. DACW 39-84-M-4797.

Data gathered during this investigation were transmitted to Mr. R. Olsen of WES immediately after completion of the investigation.

We have enjoyed working on this program with the Corps of Engineers, and look forward to future studies. If you should have any questions, please do not hesitate to call us.

Sincerely,

THE EARTH TECHNOLOGY CORPORATION (Western)

Bruce J. Douglas
Manager, Testing Services

Andrew I. Strutynsky
Andrew I. Strutynsky
Project Engineer

BJD/AIS/js
Encls.

I. INTRODUCTION

This report presents the results of the Earth Technology Corporation's Cone Penetration Tests (CPT) performed for the Waterways Experiment Station (WES), Corps of Engineers at Ririe Dam, near Ririe, Idaho. Three Cone Penetrometer Tests were performed at locations specified by WES. Two soundings included seismic velocity measurements, while the third sounding included piezometric and electrical conductivity measurements.

The intent of the CPT program was to provide soil data supporting WES evaluation of in situ conditions. The scope of work included the performance of the field CPT soundings, in-house computer reduction of the field data, and presentation of the CPT data.

Presented in plot or tabular format, this report includes: (1) standard CPT data (cone resistance, friction resistance, and friction ratio); (2) piezometric CPT data, both dynamic and during pore pressure dissipations (3) electrical conductivities and (4) seismic shear wave velocities versus depth at the sounding locations.

II. DATA ACQUISITION

Field Exploration

The Cone Penetration Test (CPT) consists of pushing a cone-tipped probe into a soil deposit while simultaneously recording the end bearing and side friction resistance of the soil to that penetration. The Cone Penetration Tests described in this report were conducted in general accordance with ASTM specifications (ASTM-D3441-79) using an electric cone penetrometer.

CPT Instruments

The CPT equipment consists of a cone assembly mounted at the end of a series of hollow sounding rods. A set of hydraulic rams is used to push the cone and rods into the soil, while a continuous record of cone and friction resistance versus depth is obtained in both analog and digital form. A specially designed all wheel drive 20 ton CPT unit was used to house and transport the test equipment. The Earth Technology Corporation also can provide other CPT systems for limited access areas.

Two different type of cone instruments were used during this study. The first cone penetrometer assembly (Figure 1) consists of a conical tip and a cylindrical friction sleeve. The conical tip has a 60° apex angle and a projected cross-sectional area of 15 square centimeters; the cylindrical friction sleeve has a surface area of 200 square centimeters. Both the conical tip and the cylindrical friction sleeve have other diameters of about 4.37 centimeters. This type of instrument was used for Soundings RD-C-2 and RD-C-3.

The second instrument is similar to the first, but the conical tip is only 10 square centimeters in projected cross-sectional area, while the sleeve has an area of 150 square centimeters (Figure 2). Both the conical tip and the friction sleeve have outer diameters of about 3.6 centimeters. This second CPT instrument can only be loaded to about 5 tons, while the first instrument can sustain over 15 tons of load. This 10 square centimeter instrument was used during Sounding RD-C-1.

The interior of each cone penetrometer is instrumented with strain gauges that allow simultaneous measurement of cone tip and friction sleeve resistance during penetration. Continuous electric signals from the strain gauges are transmitted by a cable in the sounding rods to analog and digital data recorders in the CPT truck. The continous analog recordings of subsurface soil resistance were evaluated and used in the field for planning phases of the investigation.

Piezometric CPT

A piezometric transducer was added to the 15 square centimeter CPT instrument for Sounding RD-C-2. The piezocone assembly includes a pore pressure transducer and saturated porous filter element. The piezocone design used for this study has the transducer ported to the middle of the conical tip of the cone instrument (termed tip sensing), and is shown in Figure 1. This particular design of piezometer system induces no known effect on cone (tip or friction sleeve) transducer output under laboratory calibrations. Pore pressures are all internal to the cone tip. Thus, standard cone soundings and piezocone soundings with this design generally appear identical.

Another design which is commonly used, but was not used during this study, has the transducer ported just ahead of the friction sleeve but behind the cone tip (termed side-sensing). This piezocone design interconnects the entire cone tip-friction sleeve junction with the piezometer system. Thus, any pore pressures acting on the partially exposed back area of the cone tip (and front of friction sleeve) can be measured. However, based upon observations in recent research programs, it is known that introduction of this piezometer may also effect standard cone tip and sleeve readings due to interaction of piezometer system with both the cone and friction sleeve.

The key area of concern in any dynamic piezometer system is the maintenance of system saturation. If a high degree of saturation is not maintained, poor response to in situ generated pore pressure transients can be expected.

The first step in piezometer saturation is the deaeration and saturation of piezometer elements under a very high vacuum. The piezometer elements used during this investigation consisted of the piezocone transducer tip, saturating liquid (90-10 water-glycol mixture), porous ceramic filter stone and non-porous protective membrane. All of these elements were inserted into a specially-designed deaeration chamber, deaired, and then flooded with the saturating liquid. The elements were assembled below the surface of the saturating liquid, deaired again, and sealed by slipping the protective membrane over the now fully saturated piezocone tip. All deaerations were performed at a vacuum of at least -29 inches of mercury.

We believe that the lack of a common industry procedure and understanding of the need for saturation presents a serious limitation to the routine use of the piezocone for research or other testing. A definite need is apparent for the verification of level of piezocone saturation, analogous to measurement of the geotechnical laboratory sample "B" parameter. Further, equipment must be developed to allow simple and quick field verification of piezocone saturation.

The sealed piezocone was then removed from the deaeration chamber, and was ready for testing. During a sounding, soil shear stresses burst the protective membrane. The porous filter was then in direct hydraulic contact with the surrounding soil.

Loss of piezocone system saturation during penetration of partially saturated soils above the water table presents an obstacle to piezocone data acquisition. Thus, WES drilled and cased Sounding RD-C-2 to a depth of about 82.5 ft. to prevent contact of the piezometric elements with unsaturated soil above the water table. The casing was left dry, due to concerns about hydro-fracturing the dam core. The piezocone instrument and rods were lowered through the dry casing to saturated soils below the casing. The sounding was then performed as is normally done.

Use of a dry casing rather than a water-filled casing may not positively ensure maintenance of piezometer saturation. The protective membranes may tear during lowering of the CPT instrument through the dry casing. If at all possible, piezometric CPT are recommended to be performed through water-filled casing to main tain high levels of saturation. Data collected during dissipations during this investigation appear to indicate maintenance of system saturation.

CPT Electrical Conductivity

A CPT Conductivity Tool (Figure 3) mounted behind the piezometric cone instrument was used for the measurement of soil electrical conductivity in sounding RD-C-2. The downhole portion of the tool consists of a four wire-two electrode configuration excited at 2000 Hz. Two brass electrodes are insulated from the instrument housing using Teflon rings. The uphole conductivity bridge is balanced automatically. Multipliers for wide ranges of conductivity data can be controlled manually. Field readout and recording cf conductivity data is via digital display, analog strip chart, and digital tape recording.

CPT Downhole Seismic Survey

A small diameter triaxial geophone package (Figure 4) deployed behind the 10 square centimeter cone instrument was used for a seismic downhole survey at Ririe Dam. The geophone assembly contains three mutually perpendicular, 28 Hz. velocity transducers encased in a 1.75 inch diameter housing. The geophone package was hydraulically pushed into the embankment with the in situ system at 2 sounding locations, RD-C-1, and RD-C-3. Additional information on seismic equipment, procedures and analysis is presented in appendix A.

DATA REDUCTION

CPT data reduction involves inputting field data recordings into The Earth Technology Corporation's in-house computer and subsequently computer processing that information. Computer plots and tabulations of the reduced CPT data are presented in this report. All data presented in these figures were subject to quality control checks at intermediate and final stages of processing.

Interpretation of CPT Data

Cone Penetrometer Test data can be used to identify soil type and to derive a number of soil strength parameters needed for geotechnical evaluations. Data collected are presented in Figures 5 through 8. The calculated friction ratio (friction resistance divided by cone resistance in percent) is used as an indicator of Soil Behavior Type. Granular soils typically have low friction ratios (1½ to 2 percent) and high cone resistance, while cohesive soils have high friction ratios (typically more than 4 percent) and low cone resistance. Mixtures of granular and cohesive soils have intermediate combinations of cone resistance and friction ratio. Computer processed geotechnical parameters can be evaluated through the use of classification charts obtained from site specific correlations as described in Reference 1 and 2.

Interpretation of Piezometric Data

Discussion of piezometric data is not detailed herein due to the non-standard research nature of the piezometric test. Test results are highly dependent on transducer geometry and transducer state of saturation. The piezometric CPT presented in this report were performed with a transducer ported to be the face of the conical CPT tip. The transducer was highly saturated before lowering it into the soil. Continuous data obtained during Sounding RD-C-2 are presented in Figure 6b, while pore pressure dissipation data are presented in Figure 8, and Tables 1 through 4.

Interpretation of Conductivity Data

The conductivity data presented for Sounding RD-C-2, Figure 6c, expressed in units of mho per meter X 10,000, were adjusted to values of conductance. The cell constant used for this adjustment was determined for a specific condition of water immersion. The cell constant under these conditions is about 0.08 cm^{-1}. This electrical para meter may vary depending on the penetration of the electric field into the soil.

Changes in soil conductivity are primarily due to the following factors:

1. Change in soil degree of saturation. Electrical conductivity is highly dependent on the amount of electrolyte available for conductance.

2. Change in soil type. Soil type changes can produce major changes in soil conductivity. For example, clays conduct much better than granular soils.

3. Change in soil density. The denser a soil is, the fewer the available paths for electrical conductance. Changes in density typically produce minor changes in soil conductivity.

4. Changes in pore fluid chemistry. Pore fluids play the major role in soil conductivity since soil minerals are typically quite non-conductive. For example, as the salinity of the pore fluid increases, conductivity of the fluid and soil also increases. When interpreting CPT electrical conductivity data it is important to note that the measured conductivity is a gross value for the combined soil and pore fluid system. The ratio of the pore fluid conductivity to the combined soil and pore fluid conductivity is termed the formation factor, F. For dense saturated soils the formation factor is expected to be greater than about 3 or 4. Thus, the conductance of the pore fluid, by itself, is at least 3 to 4 times that measured in the soil-pore fluid combined system.

The preciseness to which the conductivity tool can delineate an interface is influenced by the geometry of the electrode placement. The measured conductivity is controlled by the soil and pore fluid conditions local to each of the two electrodes. The electrodes are separated by 6½ inches. When an interface between a region of lower conductivity and a region of higher conductivity, such as a ground water table, is traversed with the conductivity tool, the measured conductivity will increase continuously from the point when the downhole electrode first penetrates the interface to a maximum when both electrodes have penetrated the interface. During data processing, the measured conductivity is analyzed as representing the conductivity of a point halfway between the two electrodes.

The thinnest layers the conductivity tool can respond to fully (i.e. conductivity measurement to reach full value within the layer) is limited by the electrode spacing, in this case 6½ inches. Resolution of layers thinner than

6½ inches is possible, to a limit of about the electrode thickness of 0.75 inches. However, the full value of conductance will not be measured in layers thinner than 6½ inches.

General Site Conditions

The CPT data revealed the embankment core to be highly homogenous in terms of soil type as would be expected, but slightly variable in terms of compaction. In general, compaction levels appear to be very high. Sounding RD-C-1 shows somewhat less compacted soil at about 23, 29 to 31, and 61 to 64 ft. of penetration. Friction ratios appear to be increasing between 47 and 63 ft. of penetration. A different soil type was penetrated below about 64 ft. of penetration during this sounding, but in no other sounding. The near zero friction sleeve reading at 45 ft. is anomalous.

Sounding RD-C-02 reveals similar CPT data below the drilled and cased interval of 0 to 82.5 ft. Somewhat less compacted zones are interlayered with more compacted zones between 97 and 117 ft. penetrations. The friction ratio is somewhat higher in this sounding than in RD-C-1. This may be due to different degrees of saturation between the two soundings, or due to increased confining pressures. Deep homogenous strata often show an increasing friction ratio with depth. This trend may readily be observed in sounding RD-C-3. This effect is not thought to be associated with changes in soil type with depth, but to differing response of cone tip and friction sleeve resistance to increases in overburden pressure. Some indication of increased friction ratio was also seen between 47 and 63 ft. of penetration in Sounding RD-C-1. Sounding RD-C-03, completed to a depth of about 150 ft., also reveals data highly similar to that recorded during the first two soundings. Somewhat less compacted zones

are evident at 97 ft., 108 to 111 ft., and at 135 ft. The friction ratio increases with depth, probably as a response to increased overburden stress, rather than to changes in soil type.

Data collected in Soundings RD-C-2 and RD-C-3 are from below the depths investigated in RD-C-1. Thus, no overlapping data exists for cross correlation between the 10 square centimeter cone instrument used in RD-C-1 and the other soundings. It should be noted that two attempts were made during Sounding RD-C-1, and RD-C-3 was performed only to supplement data on soils not penetrated during Sounding RD-C-1. All of these attempts were beyond the scope of work as was originally proposed.

TABLE 1

PORE PRESSURE DISSIPATION TEST
SOUNDING CPT-2
DISSIPATION AT 93'

TIME MINUTES	PORE PRESSURE TSF	PEAK PRESSURE U°	
0	5.08	5.6	
.5	5.6		
1.06	5.3		
3.06	4.7		
6.06	4.1		
9.06	3.9		
11.06	3.8		
13.06	3.6		
17.06	3.4		
21.06	3.2		
25.06	3.1		
29.06	2.9		
32.06	2.9		
35.06	2.7		
37.06	2.6		

TABLE 2

PORE PRESSURE DISSIPATION TEST
SOUNDING CPT-2
DISSIPATION AT 105.6'

TIME (MINUTES)	PORE PRESSURE TSF	PEAK PRESSURE U*	
PEAK PRESSURES MISSED, TRANSDUCER OVERLOADED			
.12	38.3	38.3	
.13	37.8		
.167	36.9		
.2	36.1		
.25	34.6		
.28	33.6		
.78	24.7		
1.38	19.4		
2.28	14.2		
3.03	11.9		
4.18	10.0		
6.18	7.8		
10.18	5.8		
14.18	4.9		
18.18	4.2		
22.18	3.8		

TABLE 3

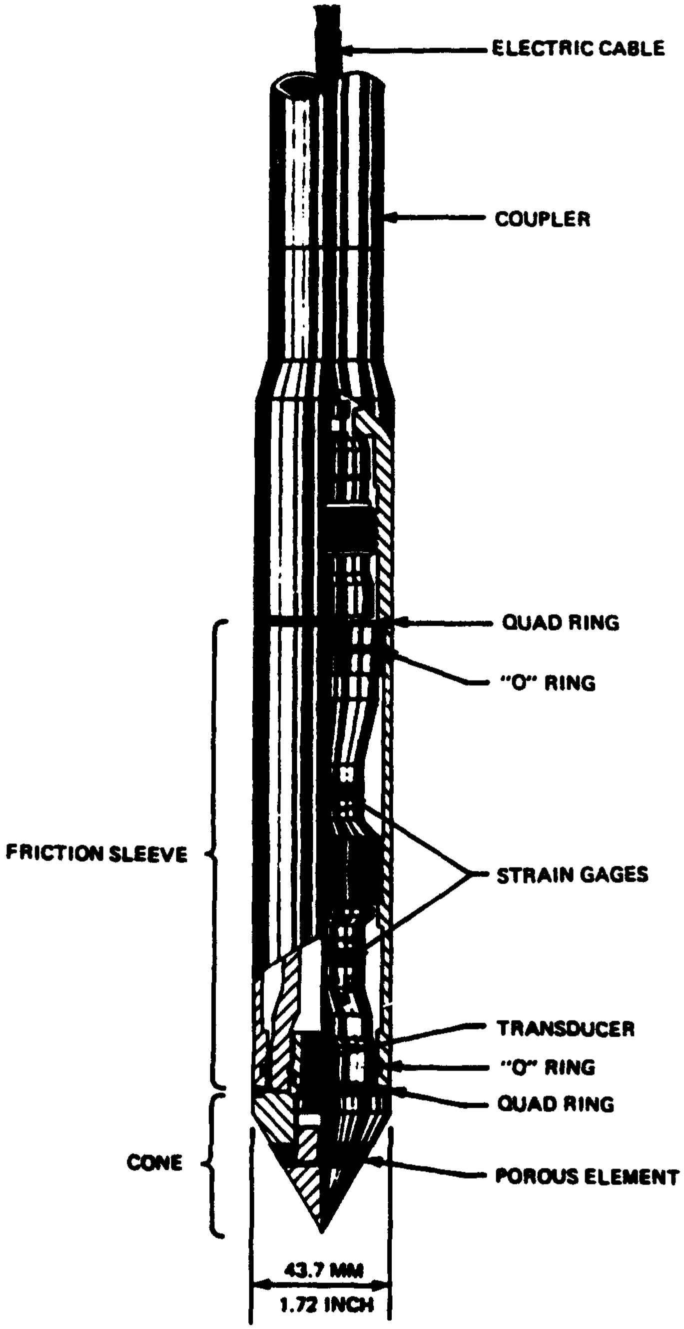
PORE PRESSURE DISSIPATION TEST
SOUNDING CPT-2
DISSIPATION AT 111.2'

TIME (MINUTES)	PORE PRESSURE TSF	PEAK PRESSURE U°	
0	34.9	34.9	
.5	25.3		
.8	21.6		
1.0	19.9		
2.17	15.0		
4.17	11.2		
6.17	9.1		
8.17	7.8		
10.17	6.9		
12.17	6.2		
14.17	5.6		
16.17	5.2		
18.17	4.9		
20.17	4.6		
22.17	4.4		
23.17	4.2		

TABLE 4

PORE PRESSURE DISSIPATION TEST
SOUNDING CPT-2
DISSIPATION AT 128.2'

TIME (MINUTES)	PORE PRESSURE TSF	PEAK PRESSURE U°	
0	14.7	14.7	
.4	9.8		
.7	8.7		
1.1	7.5		
1.8	6.1		
2.08	6.0		
2.3	5.8		
2.58	5.7		
2.83	5.6		
3.08	5.5		
3.83	5.3		
4.08	5.3		
4.83	5.0		
5.08	5.0		
6.04	4.6		
8.04	4.4		
10.04	4.3		
12.04	4.1		



The Earth Technology Corporation

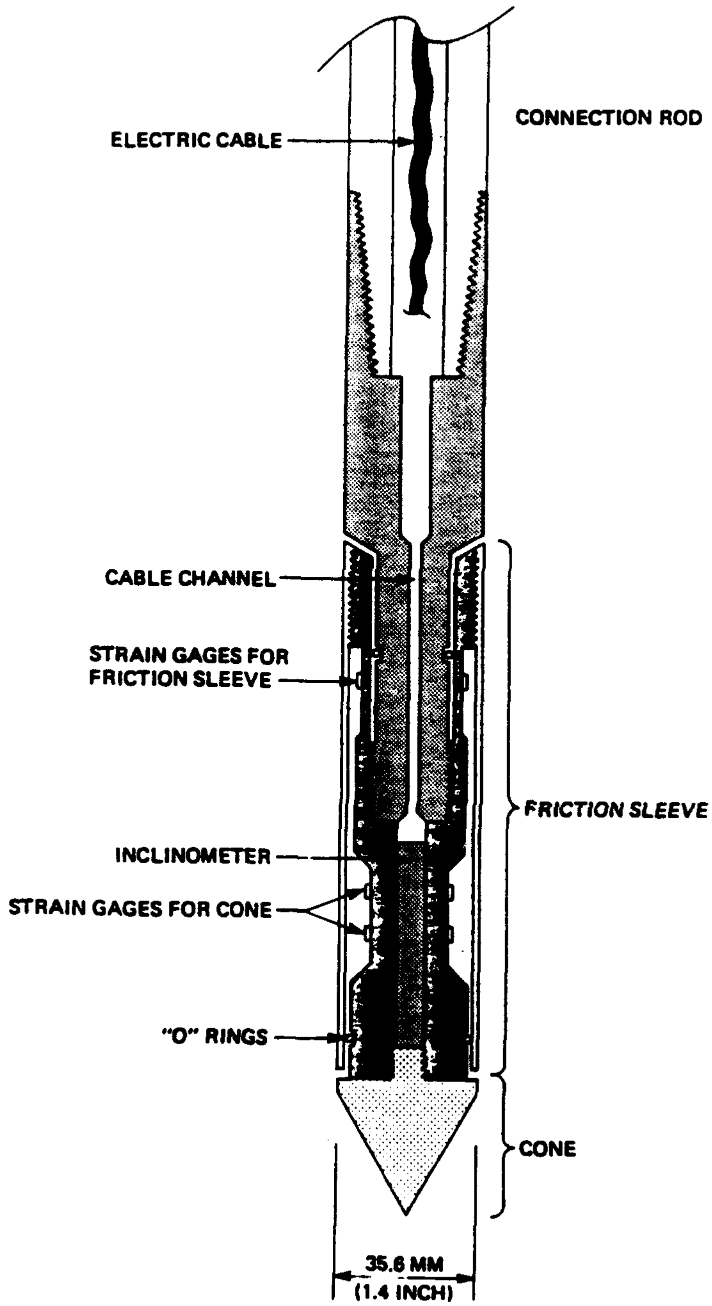
PROJECT NO.: 86-140

RIRIE DAM

15sq cm 20 TON ELECTRIC FRICTION CONE PENETROMETER WITH PORE PRESSURE ELEMENT

12-86

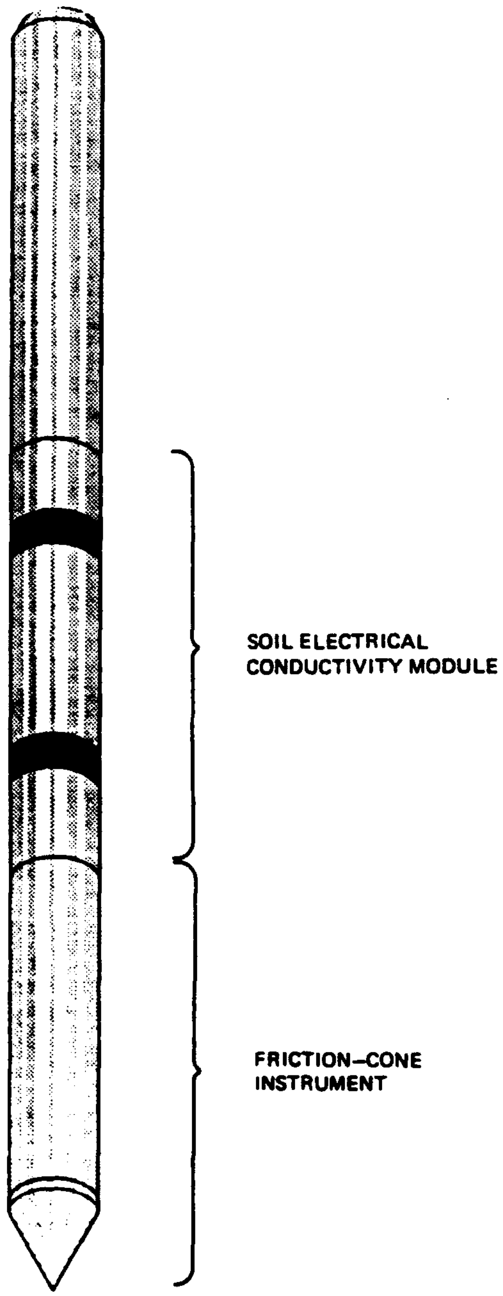
FIGURE 1



The Earth Technology Corporation	PROJECT NO.: 85-140 RIRIE DAM

10sq cm 5 TON ELECTRIC FRICTION CONE PENETROMETER

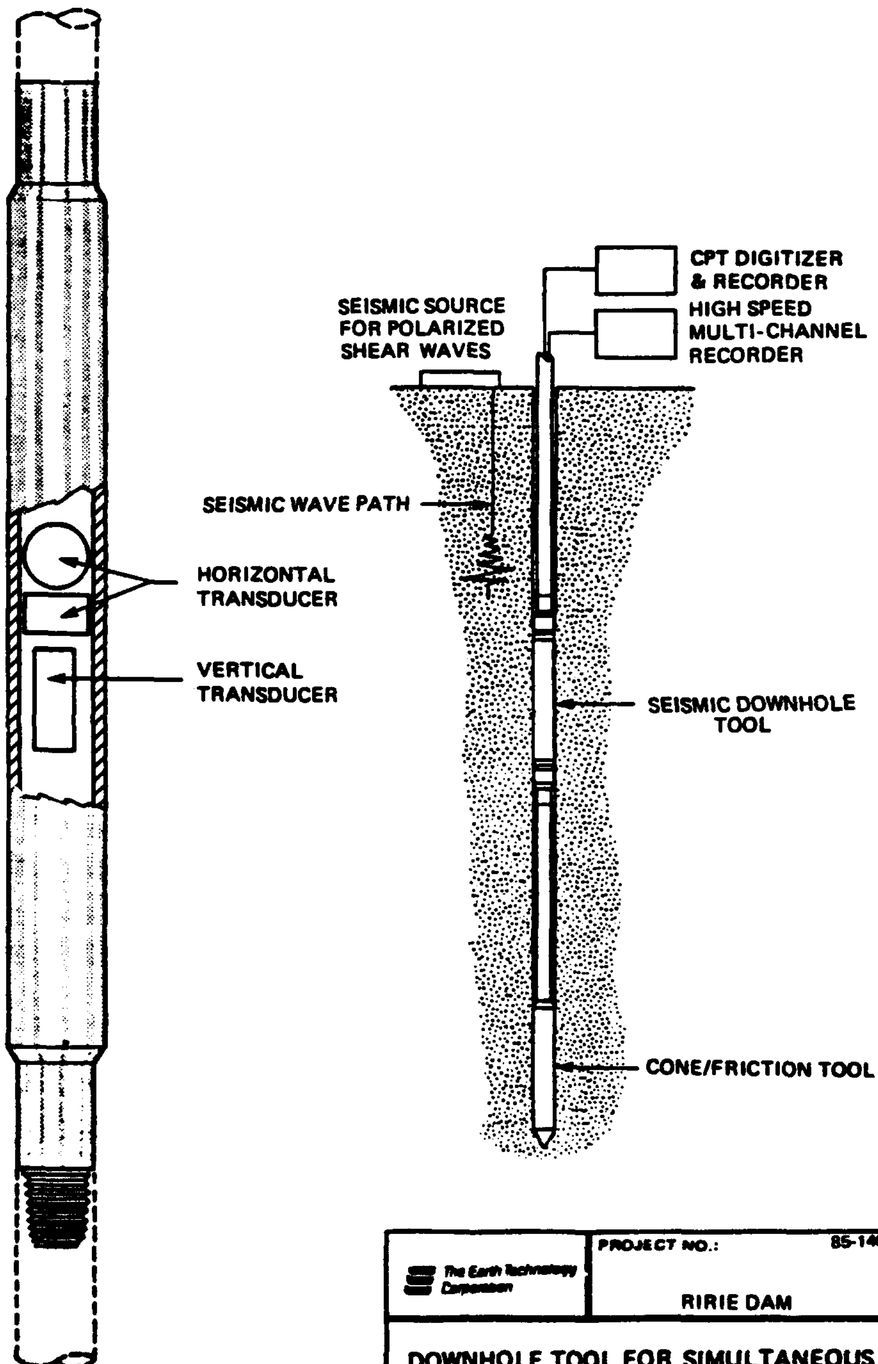
12-84 FIGURE 2



The Earth Technology Corporation	PROJECT NO.: 85-140 RIRIE DAM

20 TON CONE WITH SOIL CONDUCTIVITY MODULE

12-84 FIGURE 3



The Earth Technology Corporation

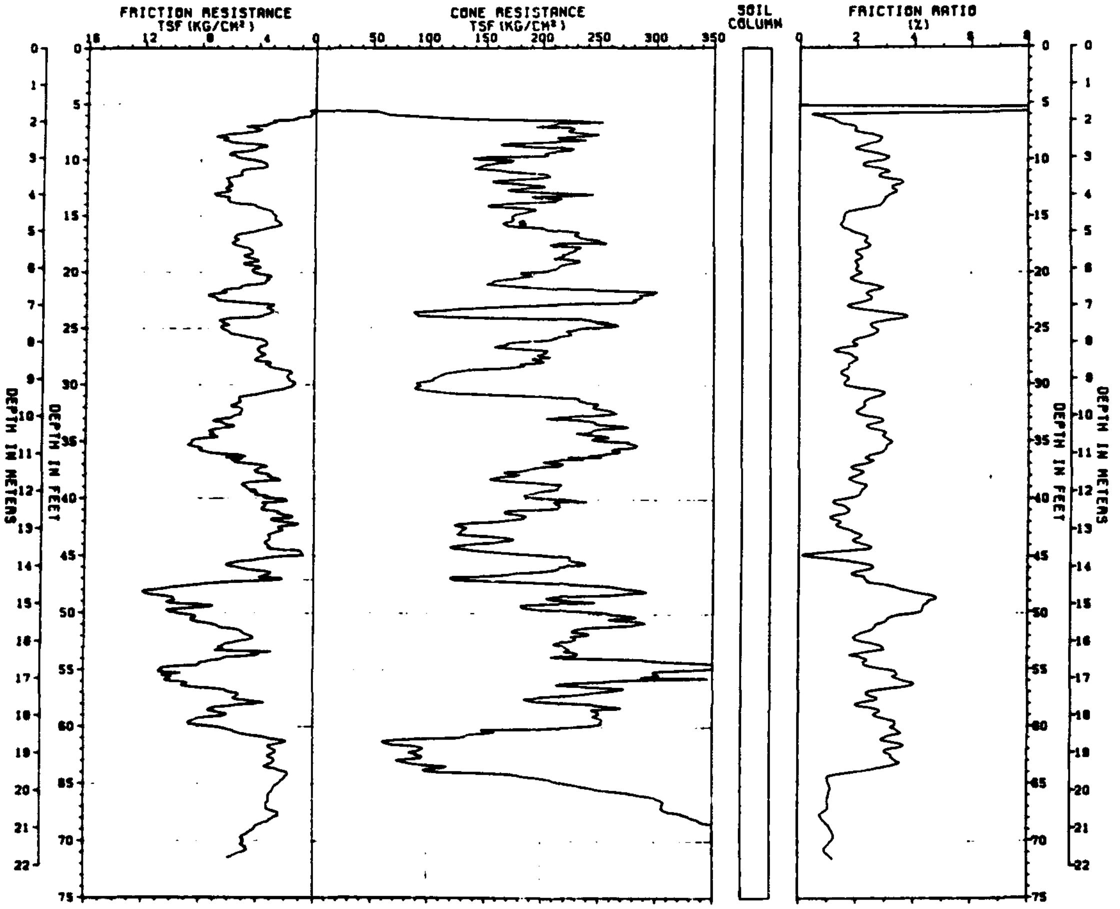
PROJECT NO.: 85-140

RIRIE DAM

DOWNHOLE TOOL FOR SIMULTANEOUS CPT/SEISMIC DOWNHOLE LOGGING

12/84

FIGURE 4



SOUNDING PERFORMED WITH A 10 SQ. CM. END AREA, 150 SQ. CM. FRICTION SLEEVE CPT INSTRUMENT. SEISMIC SHEAR WAVE VELOCITIES WERE OBTAINED DURING WITHDRAWAL OF THIS INSTRUMENT, USING AN IN-LINE GEOPHONE ASSEMBLY.

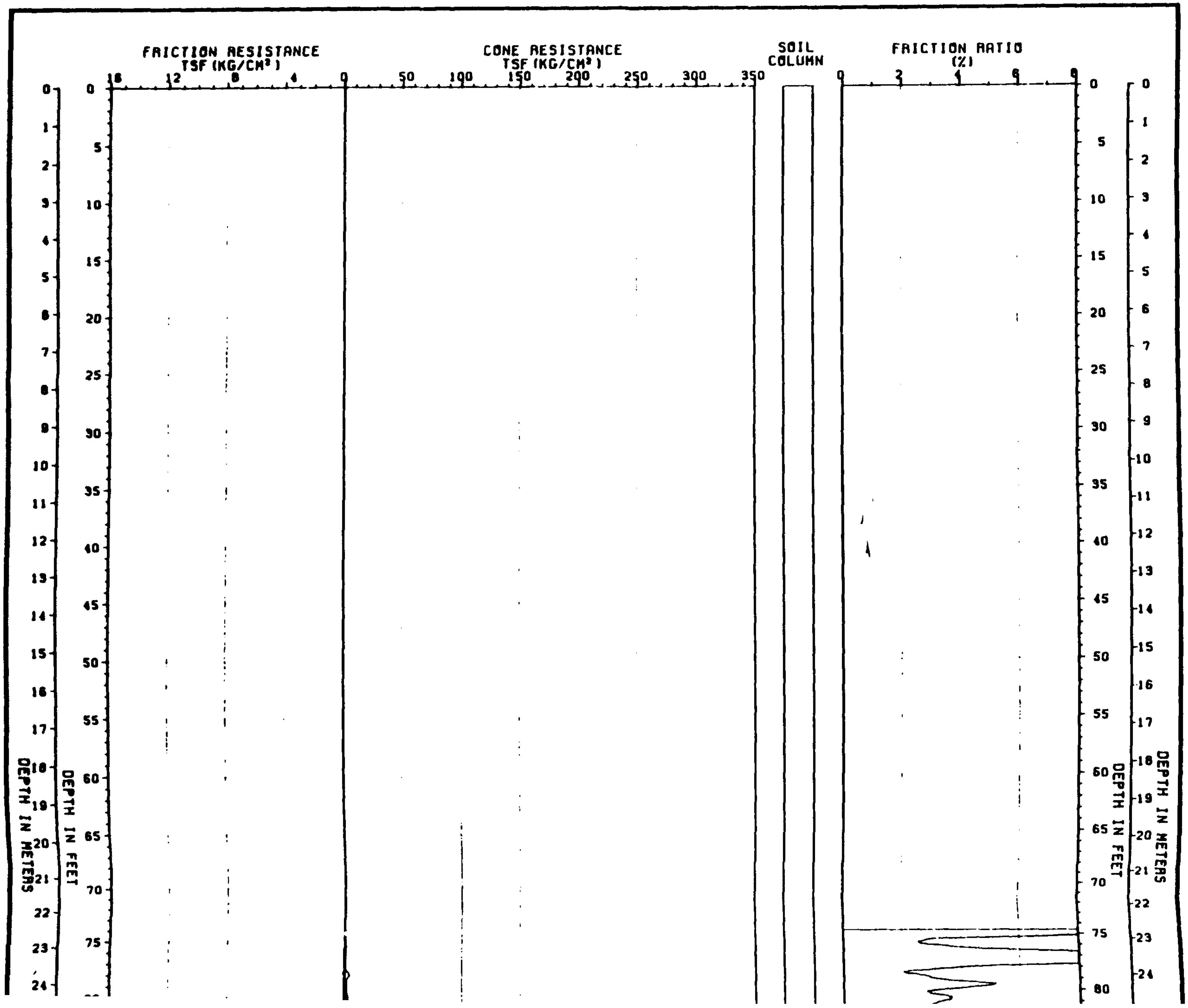
PROJECT: AIRIE DAM
PROJECT NUMBER: 85-140-05
INSTRUMENT NUMBER: F5CK230
DATE: 11/14/84

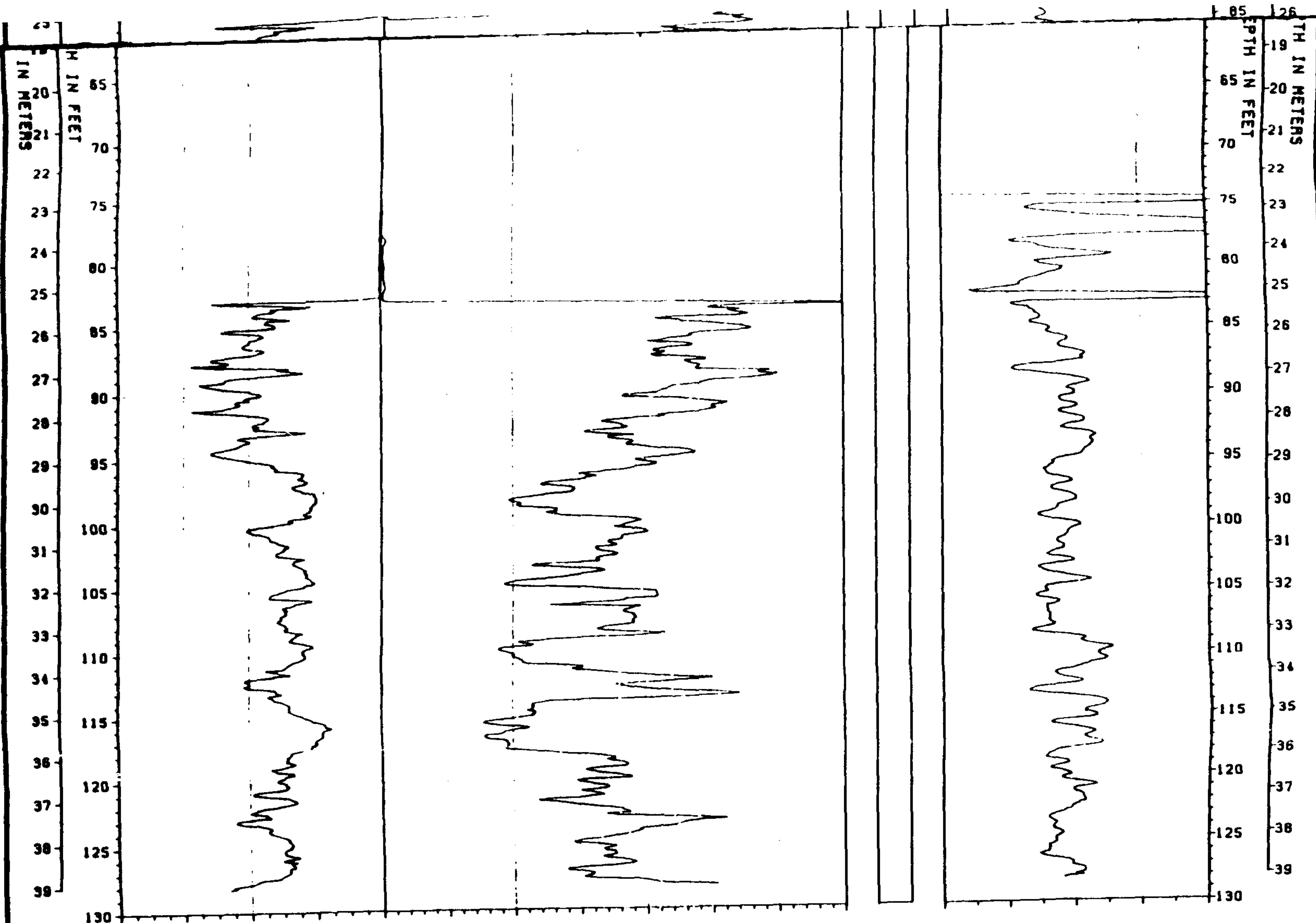
The Earth Technology Corporation

CONE PENETROMETER TEST

PROBE: AD-C-1

FIGURE 5


FRICTION RESISTANCE
TSF (KG/CM²)
CONE RESISTANCE
TSF (KG/CM²)
SOIL
COLUMN
FRICTION RATIO
(%)
DEPTH IN FEET
DEPTH IN METERS



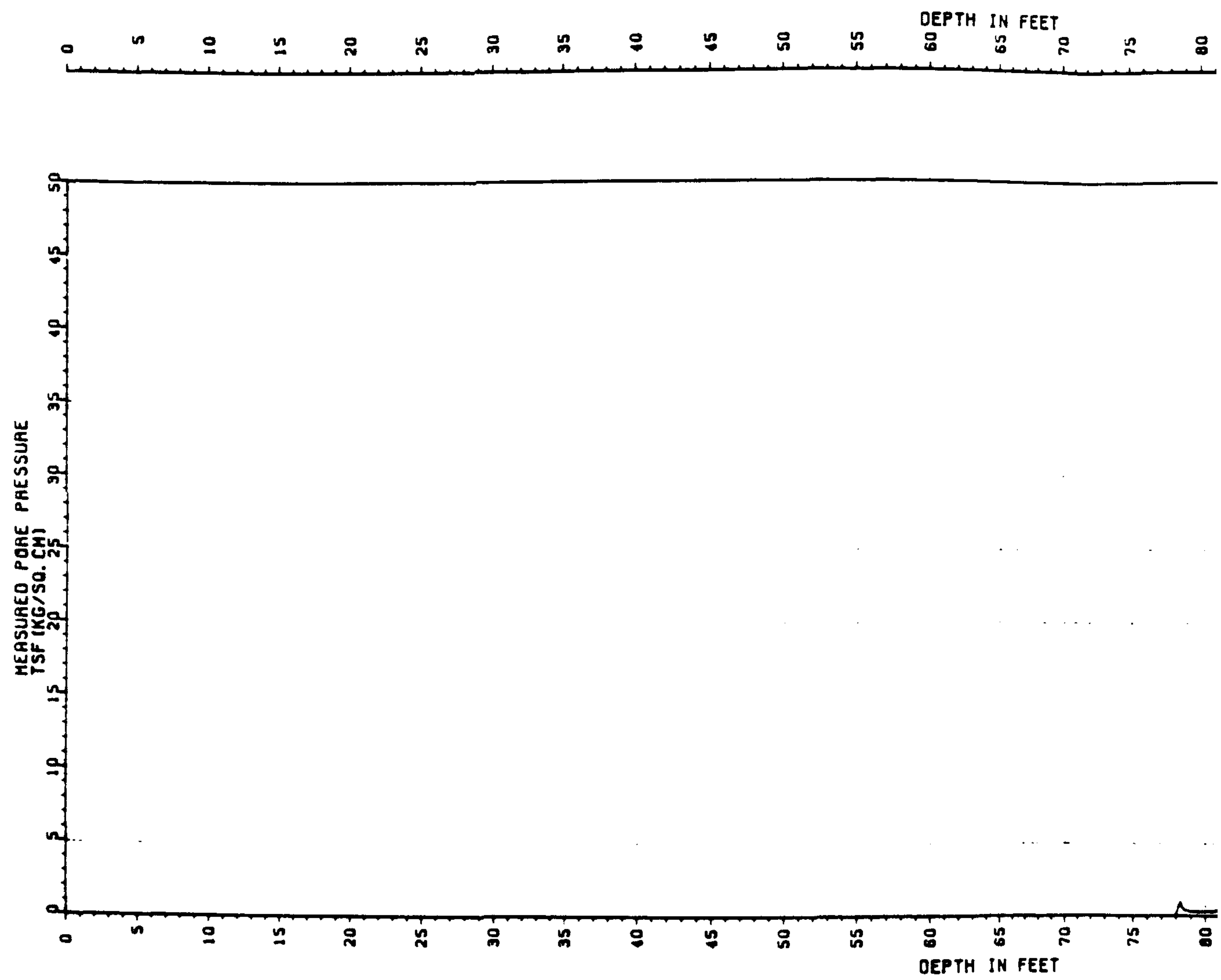
SOUNDING PERFORMED WITH A 15 SQ. CM. END AREA, 200 SQ. CM. FRICTION SLEEVE, SUBTRACTION TYPE CPT INSTRUMENT. PIEZOMETRIC PRESSURES, AND ELECTRICAL CONDUCTIVITY WERE RECORDED SIMULTANEOUSLY WITH CONE AND FRICTION RESISTANCE.

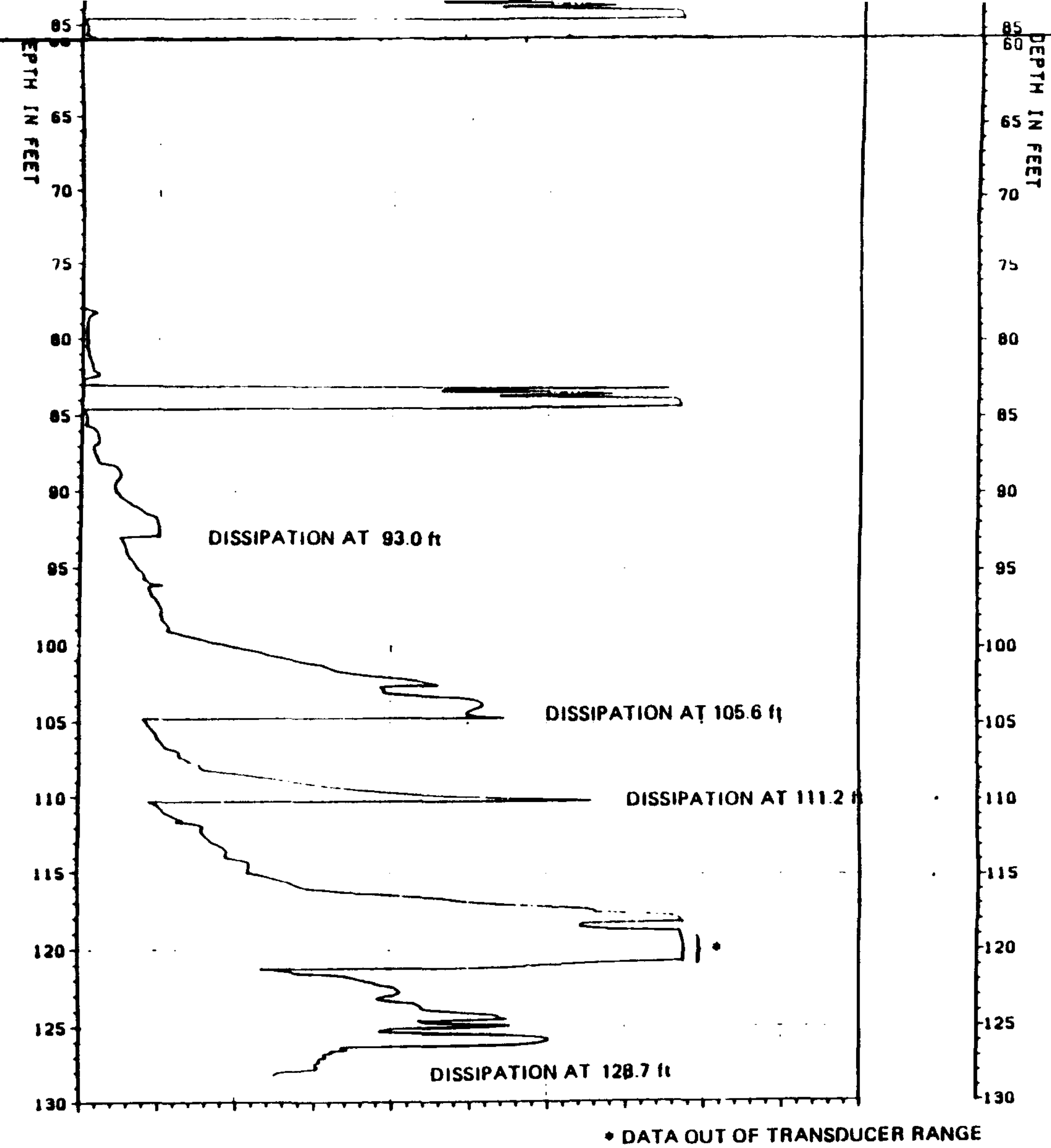
PROJECT: RIRIE DAM
PROJECT NUMBER: 85-140-05
INSTRUMENT NUMBER: F5CKE501
DATE: 11/08/84

The Earth Technology Corporation

CONE PENETROMETER TEST
PROBE: RD-C-2

FIGURE 6a


DEPTH IN FEET
MEASURED PORE PRESSURE
TSF (KG/SQ.CM)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
DEPTH IN FEET



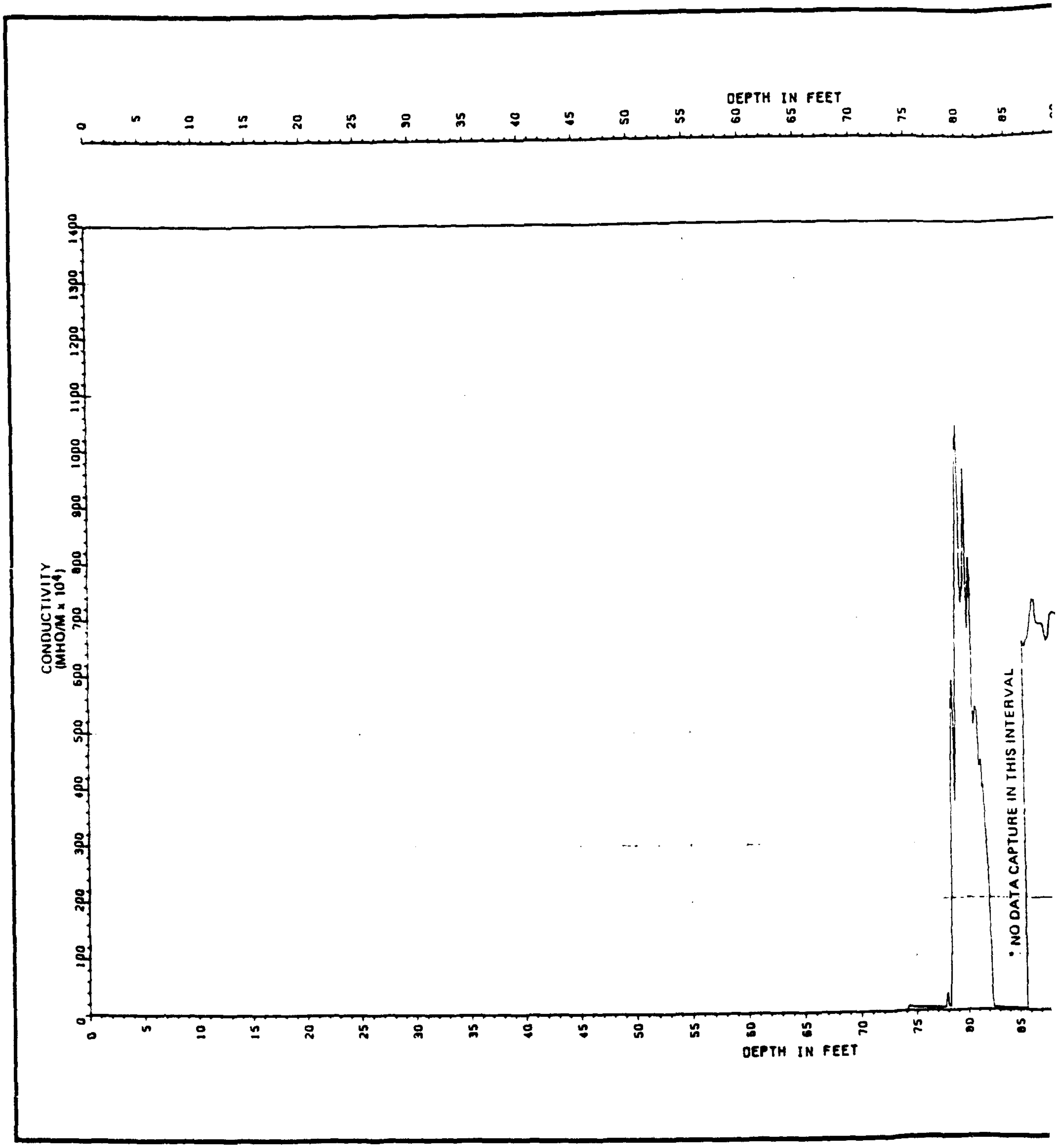
PROJECT: AIRIE DAM
PROJECT NUMBER: 85-140-05
INSTRUMENT NUMBER: FSCKE501
DATE: 11/08/84

The Earth Technology Corporation

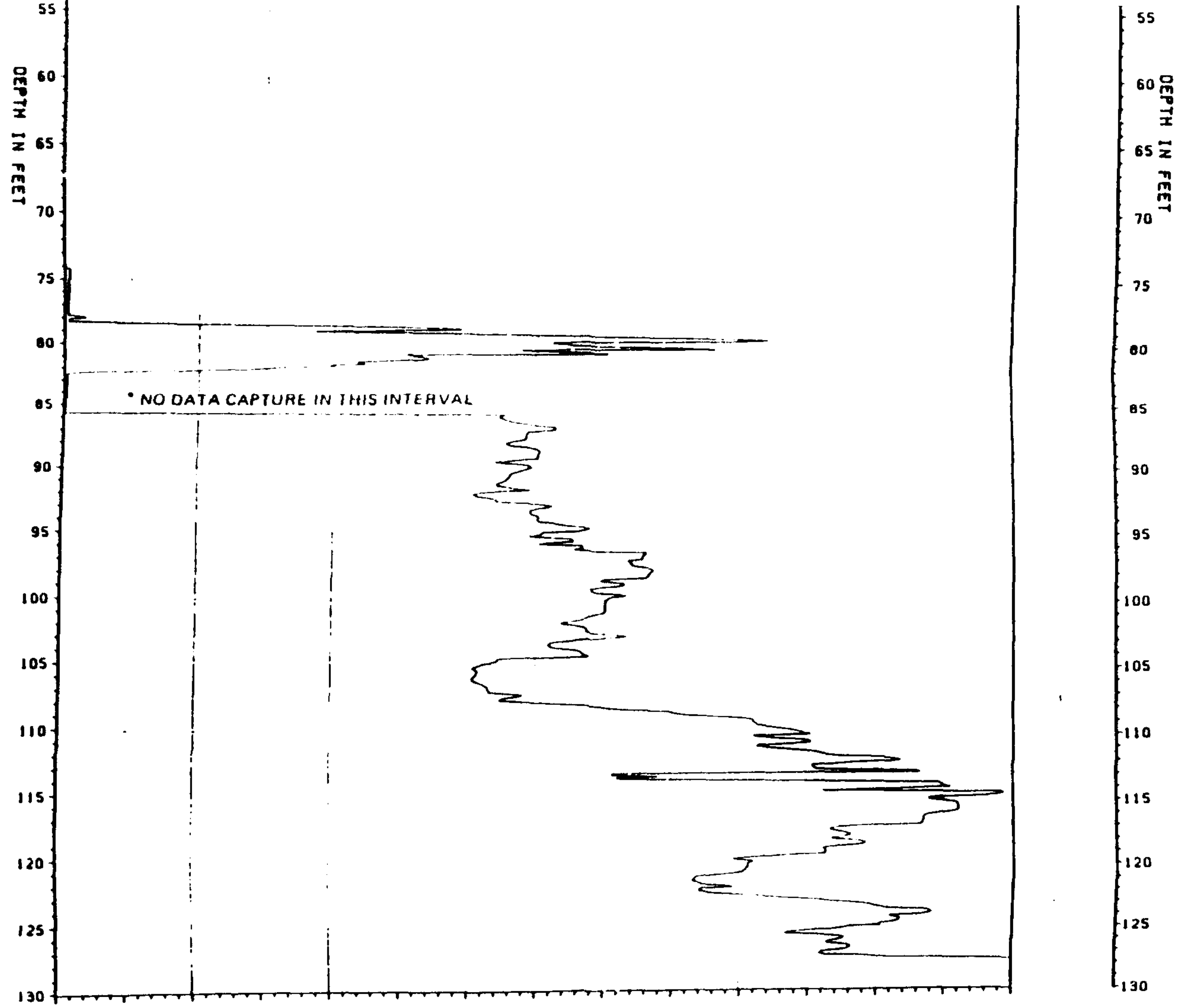
CONE PENETROMETER TEST

PROBE: AD-C-2

FIGURE 6b



DEPTH IN FEET
CONDUCTIVITY (MHO/M x 10⁴)
* NO DATA CAPTURE IN THIS INTERVAL
DEPTH IN FEET

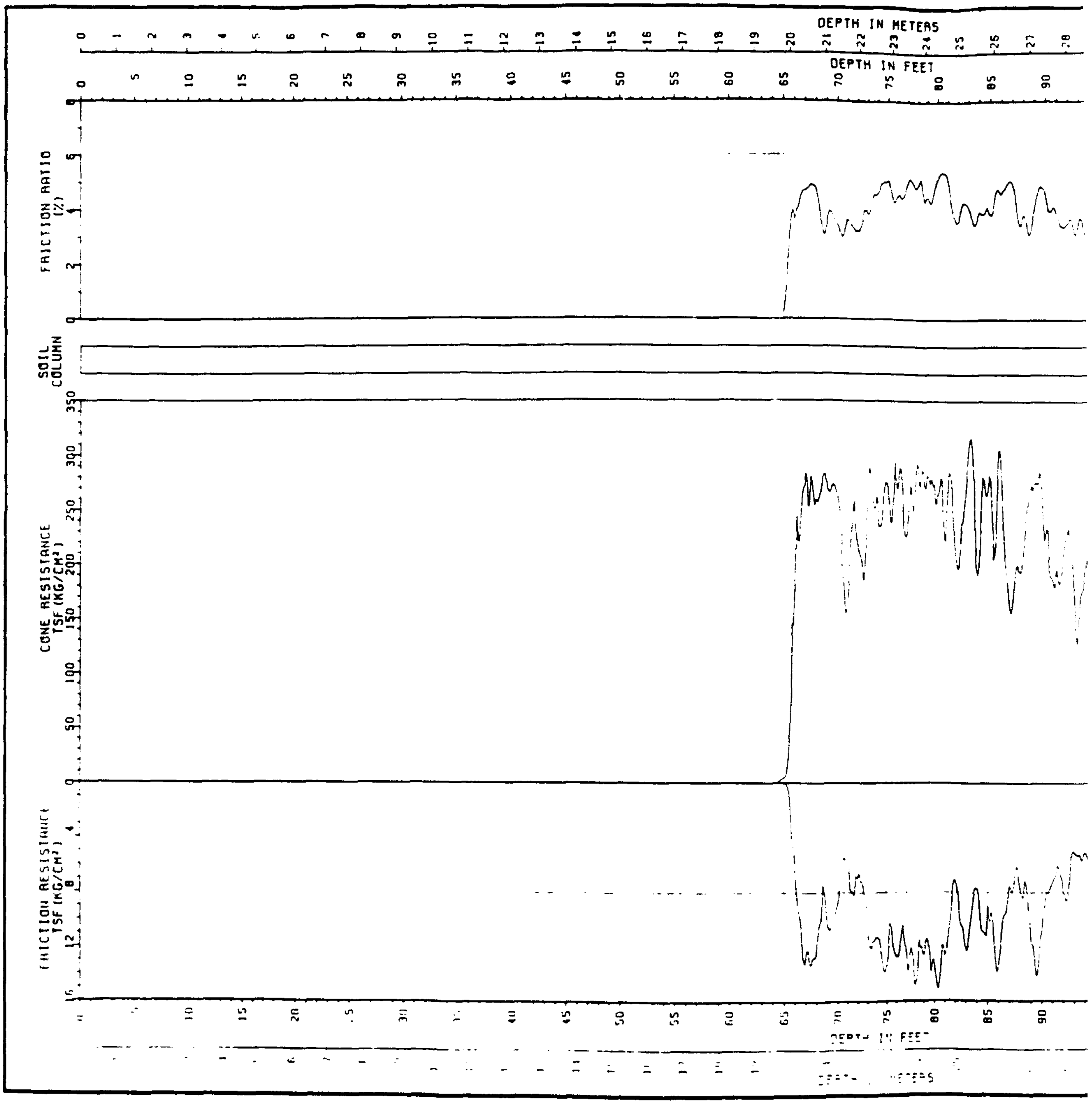


PROJECT: AIRIE DAM
PROJECT NUMBER: 85-140-05
INSTRUMENT NUMBER: F5CKE501
DATE: 11/08/84

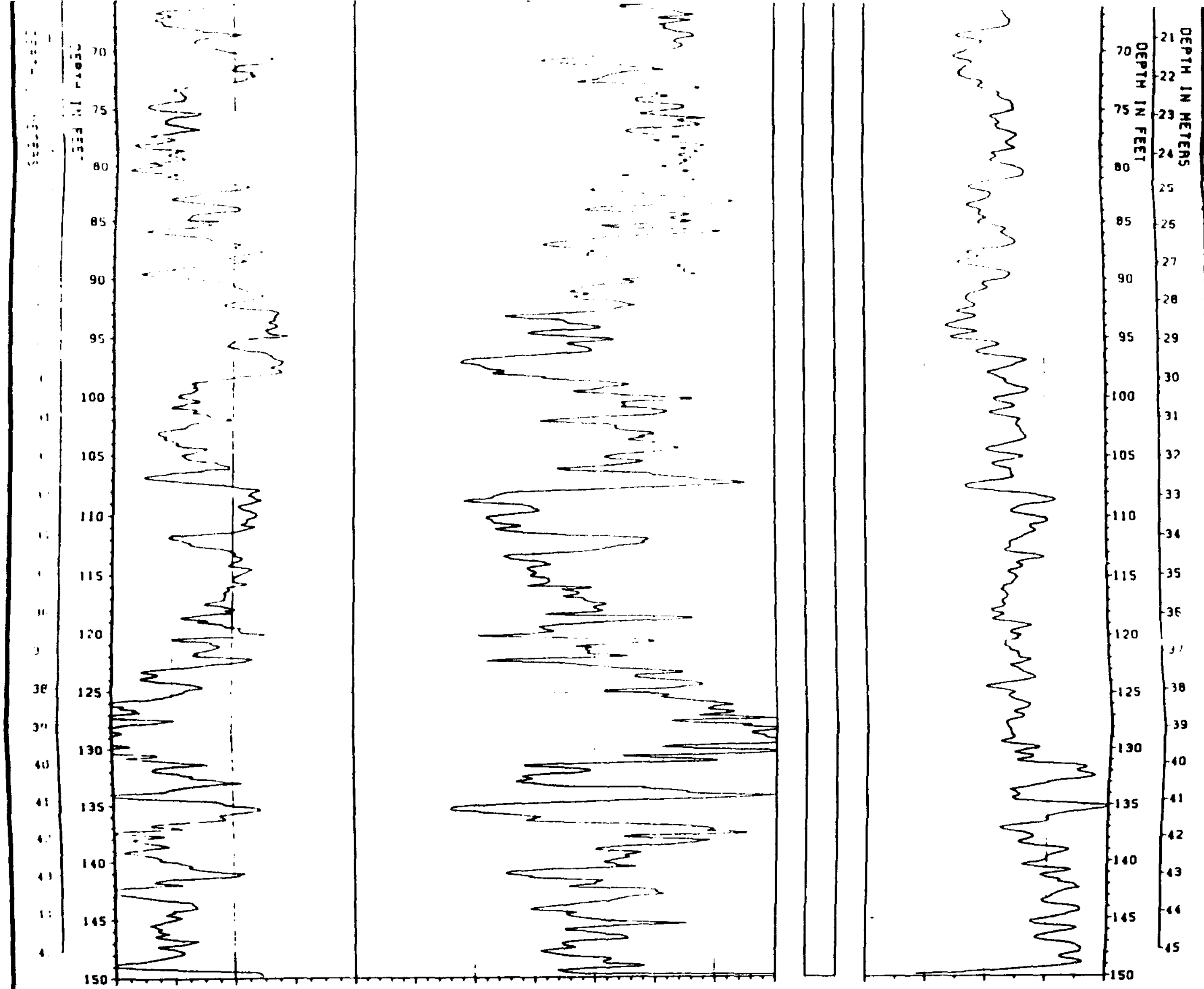
The Earth Technology Corporation

CONE PENETROMETER TEST
PROBE: RD-C-2

FIGURE 6c



DEPTH IN METERS
DEPTH IN FEET
FRICTION RATIO (%)
SOIL COLUMN
CONE RESISTANCE TSF (KG/CM²)
FRICTION RESISTANCE TSF (KG/CM²)



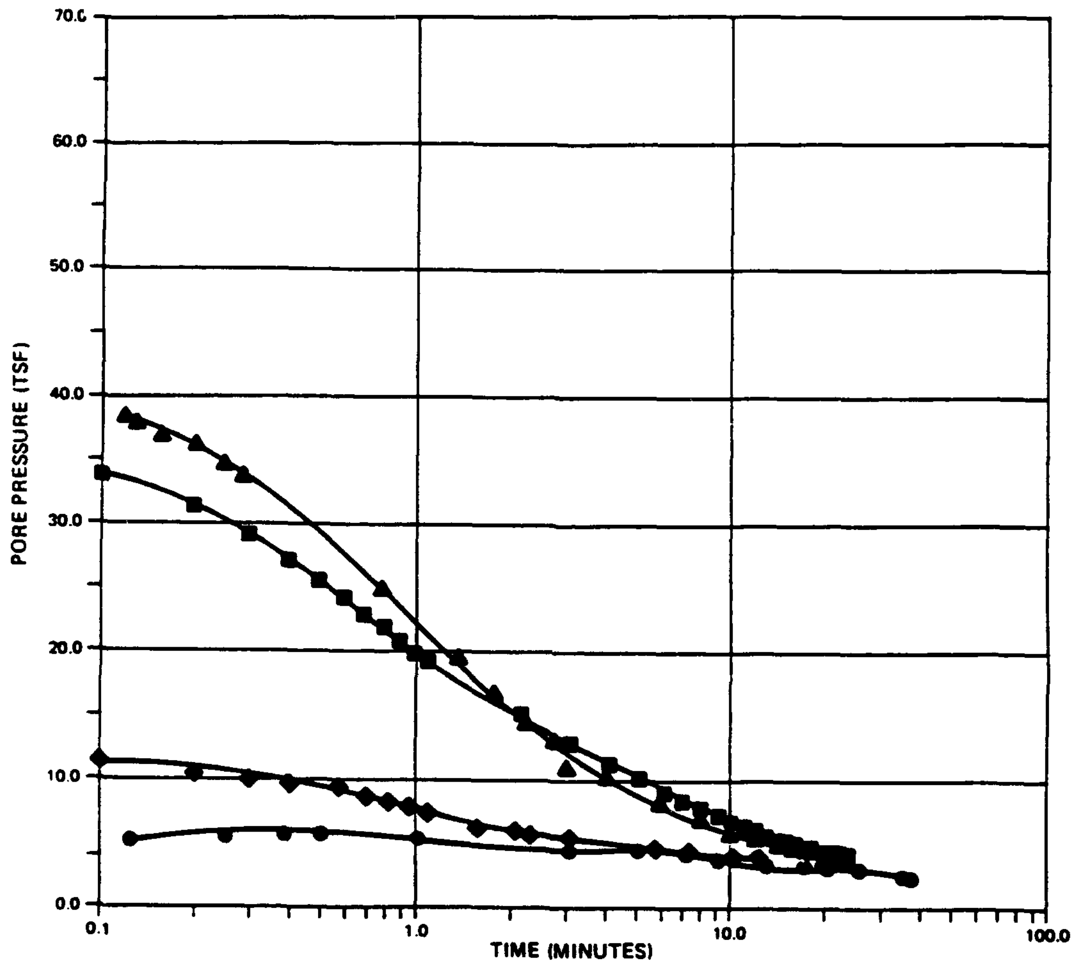
SOUNDING PERFORMED WITH A 15 SQ. CM. END AREA, 200 SQ. CM. FRICTION SLEEVE, SUBTRACTION TYPE CPT INSTRUMENT. SEISMIC SHEAR WAVE VELOCITIES WERE OBTAINED BY HYDRAULICALLY POSITIONING A GEOPHONE PROBE SUBSEQUENT TO CPT PERFORMANCE.

PROJECT: RIRIE DAM
PROJECT NUMBER: 85-140-05
INSTRUMENT NUMBER: F5CKE075
DATE: 11/15/84

The Earth Technology Corporation

CONE PENETROMETER TEST
PROBE: RD-C-3

FIGURE 7



SYMBOL	SOUNDING	DEPTH (FEET)
●	2	93
▲	2	105.6
■	2	111.2
◆	2	128.7

The Earth Technology Corporation

PROJECT NO.: 85-140

RIRIE DAM

SOUNDING RD--C--2
PORE PRESSURE DISSIPATION PLOTS
TIP SENSING PIEZOCONE

12-84 FIGURE [illegible]

APPENDIX A

INTRODUCTION

Downhole seismic velocity surveys were made in conjunction with CPT Soundings RD-C-1 and RD-C-2 at Ririe Dam. The objective of these surveys was to measure the compressional (P) and shear (S) wave velocity profiles of the subsurface materials. Velocity measurements for relatively deep material were made in Sounding RD-C-2 because Sounding RD-C-1 did not reach the desired depth.

In these surveys, the seismic waves were generated at the surface and recorded at a number of depths in the soundings. Except for the very shallow depths, the waves arriving at successively greater depths have traveled along essentially the same paths that were followed to the shallower depths. Thus, a vertical velocity profile was constructed by using travel time differences as the basis for calculating average wave velocities across successive depth intervals.

DATA ACQUISITION

Recording Instruments

Seismic waves were recorded with a twelve-channel, signal enhancement seismograph, EG&G Nimbus Model ES-1210F. The signals from each energy generation were digitized and stored in a computer-type memory inside the instrument. During data acquisition, the seismic waves were displayed on an oscilloscope screen. When the proper sequence of traces was displayed, a hard copy record with full-width timing lines (1 to 2 millisecond intervals) was made. The timing lines form the basis for measuring the time required for the seismic wave to travel from the point of energy generation (shot point) to the geophones.

GeoSpace model GSC-14-L3, 28HZ geophones incorporated in the CPT rod string were used to detect the seismic wave arrivals in the borings. The assembly contains three mutually perpendicular geophones.

Field Procedures

The general procedure for making a downhole velocity measurement is shown in Figure A-1. Seismic wave travel times were obtained by mechanically generating energy at the surface and recording the wave arrival at 5-ft. depth intervals in the soundings. The point of energy generation was located 15 ft. from the sounding on a paved surface, over riprap. The energy source was offset from the boring in an effort to reduce the amplitude of horizontally travelling energy arriving through the pavement at the CPT rods. Despite the offset, the P-wave in the soils was not identified because it was masked by first arrivals of energy travelling down the CPT rods.

The downhole measurements were begun following the CPT sounding. After each recording of seismic waves, the string was raised 5 feet and another recording was made. Shear wave energy for a record was generated by horizontal sledge hammer blows on the ends of a wooden beam lying flat on the ground. A vehicle was parked on top of the beam to provide solid coupling to the ground. The beam was oriented perpendicular to a line extending from its center to the CPT rod. The horizontal blows produced polarized S-waves. One set of traces on the records shows the output of the horizontal geophones when one end of the beam was struck. A second set of traces shows the horizontal geophones' output when the other end was struck. Since the S-waves from the two blows were oppositely polarized, the trace excursions marking their arrival at the geophones have opposite polarity.

A third set of traces recorded the energy from a vertical hammer hit on a metal plate lying on the ground. Vertical blows generate larger amplitude P-waves than horizontal blows.

Records were made in this way with the geophones located at 5 ft. intervals between depths of 5.25 and 50.25 ft. in Sounding R-C-1 and 80 and 130 ft. in Sounding R-C-2.

RESULTS

Data Reduction

The downhole records were analyzed to determine the arrival of the P and S waves at the geophone assembly. An example downhole seismogram is shown in Figure A-2. The P- and S-wave arrivals were first identified on each record. The travel times were measured from the records and corrected to an equivalent vertical time since the actual path was a slant distance between the impact point and the geophones. The corrected travel times for the downhole measurements at both soundings are plotted versus depth in Figure A-3. The velocity profiles are interpreted from these graphs by fitting straight line segments (least squares regression) through groups of adjoining data points. The slopes of these line segments equal the average seismic velocities in the interpreted, subsurface layers. Interval velocities for the S-wave were calculated for each 5 ft. interval. P-wave interval velocities were not calculated because they would not represent the soil.

Velocity Profiles

The average S-wave velocity in the upper 50 ft. is 690 fps and it is 880 fps in the bottom 45 ft. The very high velocities shown by the first arrivals (P-wave) are typical of steel rods. We have not encountered this situation on previous

CPT downhole velocity surveys, and this is the first such survey starting on a paved surface. It seems likely that the pavement carried high amplitude energy which was coupled into the rods.

Since no P-wave velocities representing soil were measured, Poisson's Ratio, Bulk Modulus, and Young's Modulus could not be calculated. Shear modulus was calculated according to the following equations:

SHEAR MODULUS, μ , (in psf)

where $\mu = CDV_s^2$

V_s = shear wave velocity in feet per second

D = density in pounds per cubic foot

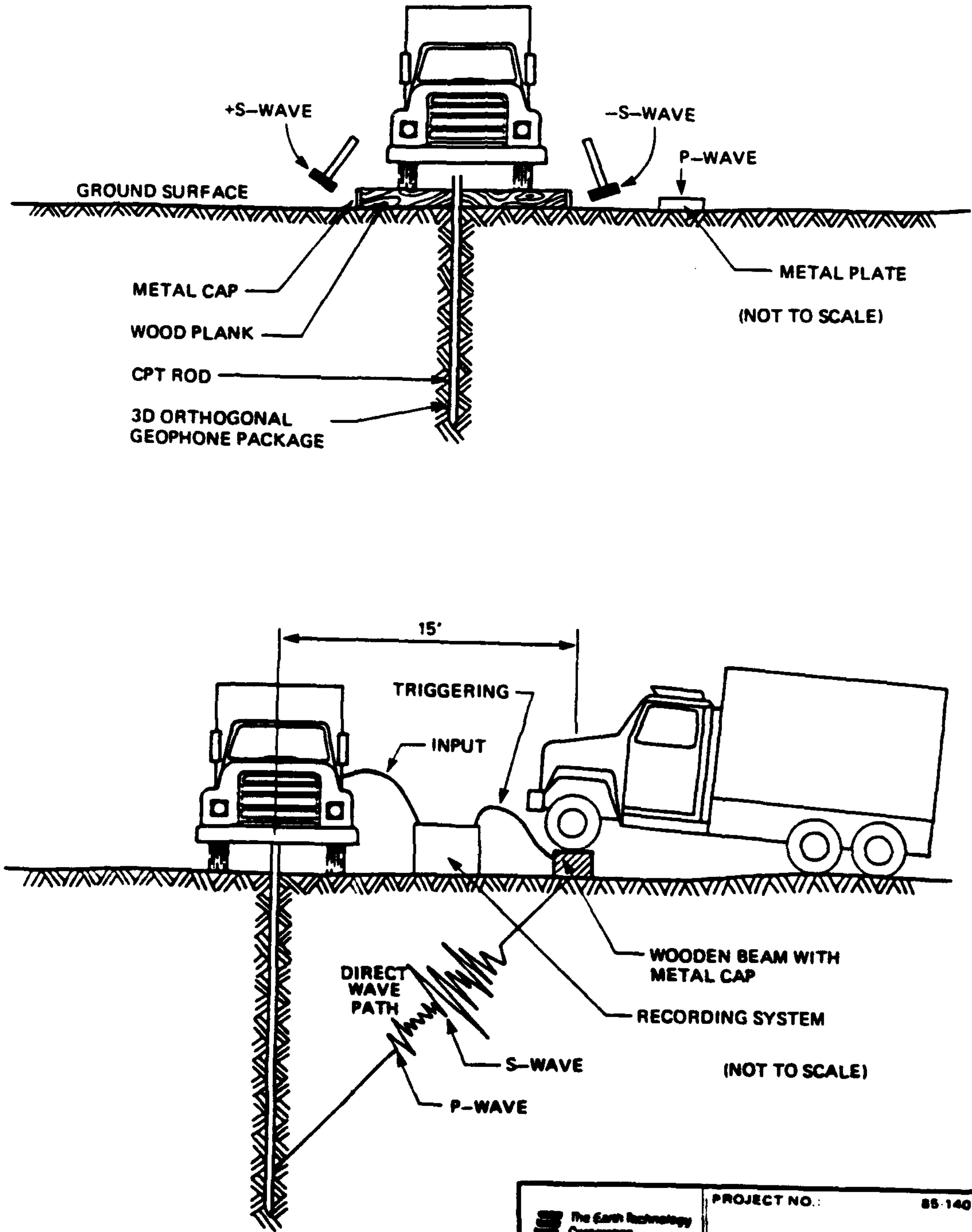
C = 3.10464×10^{-2} (constant of unit conversion)

psf = pounds per square foot

Since we do not have specific density values for these materials, moduli were calculated for 3 different densities, which probably cover the range of values which might be encountered in the dam material.

Table D-1. Shear Modulus (psf)

S-wave Velocity (fps)	Bulk Density		
	115 pcf	125 pcf	135 pcf
690	170×10^4	185×10^4	200×10^4
880	277×10^4	301×10^4	325×10^4



The Earth Technology Corporation

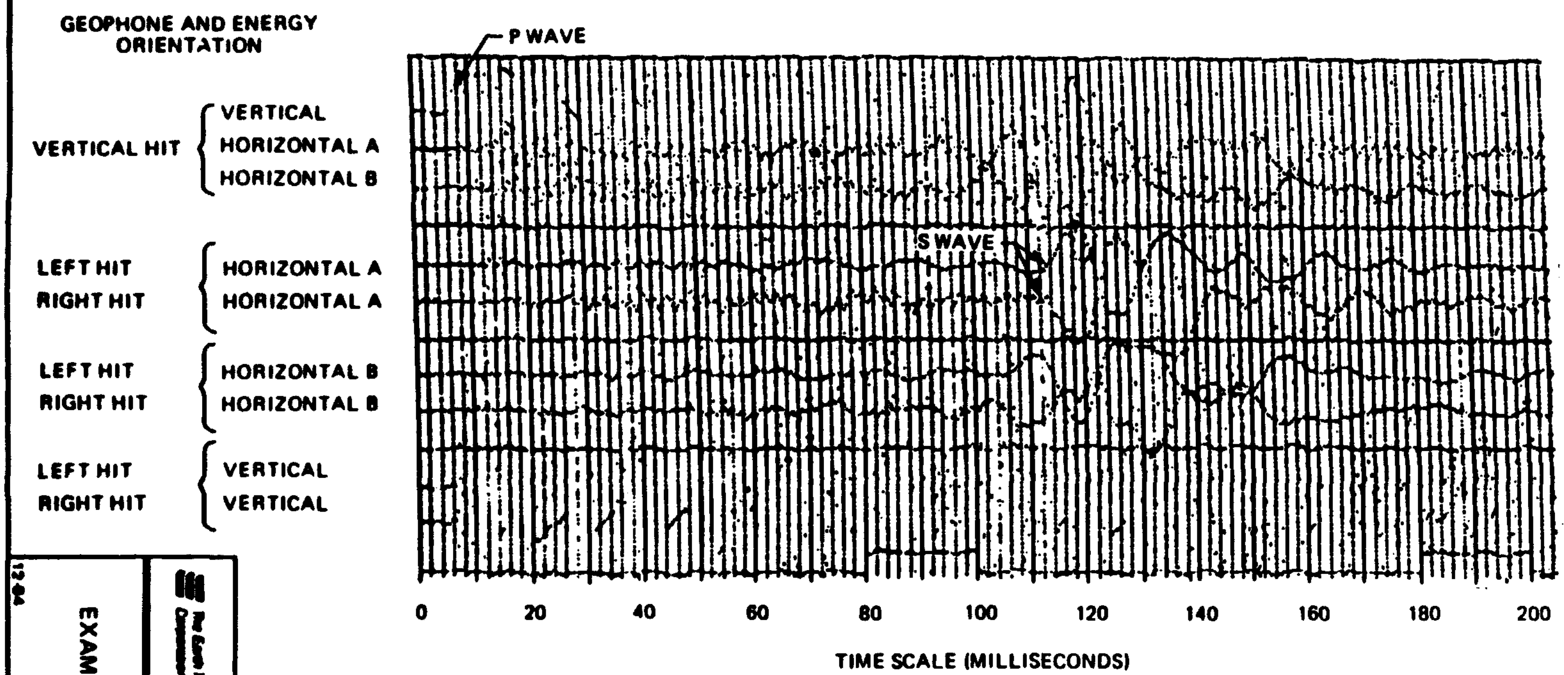
PROJECT NO.: 85-140

RIRIE DAM

DOWNHOLE VELOCITY SURVEY
MEASUREMENT PROCEDURE

12 84

FIGURE A-1



SEISMOGRAM RECORDED FROM 85 FEET DEPTH IN SOUNDING RD-C-2

The Earth Technology Corporation

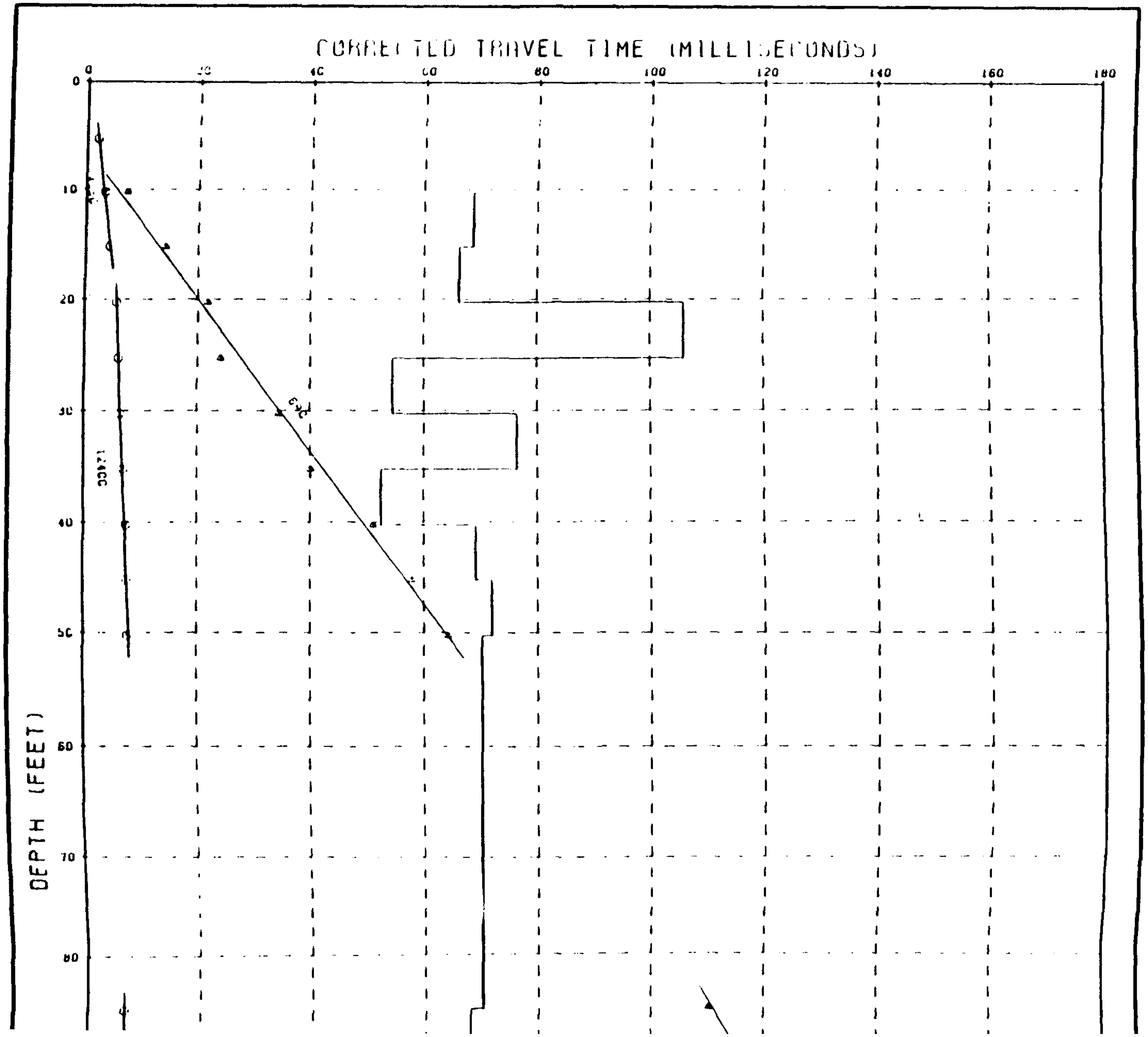
PROJECT NO. 85-140

RIRIE DAM

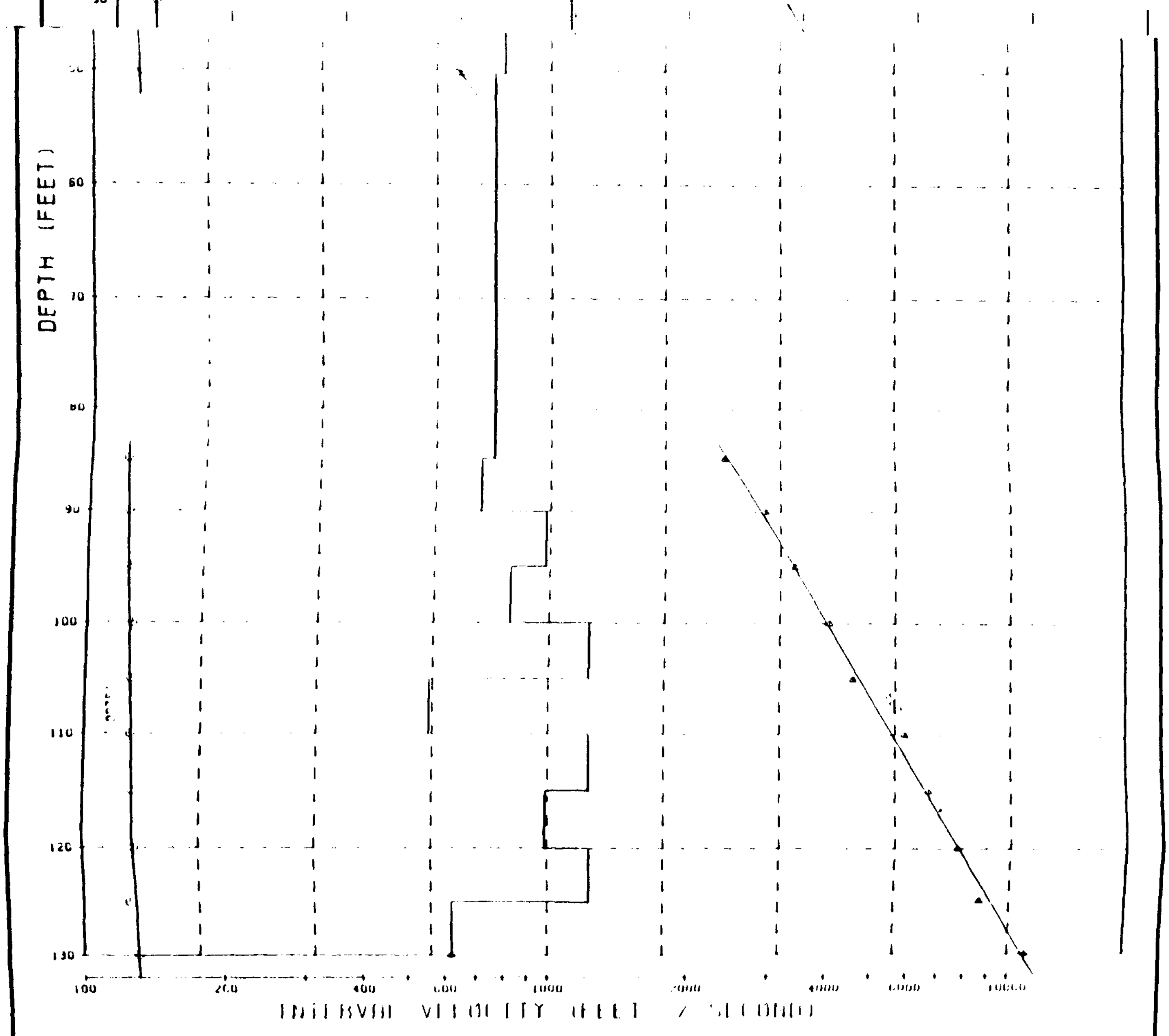
EXAMPLE DOWNHOLE SEISMOGRAM

12-84

FIGURE A-2



CORRECTED TRAVEL TIME (MILLISECONDS)
0
20
40
60
80
100
120
140
160
180
DEPTH (FEET)
0
10
20
30
40
50
60
70
80
69C
124CC



The Earth Technology Corporation

PROJECT NO 88 140

RIHIE DAM

DOWNHOLE VELOCITY
SURVEY RESULTS
SOUNDINGS RD C 1 & 3

12 84

FIGURE A 3

APPENDIX H: REPORT SUBMITTED BY LESLIE F. HARDER, JR.

(August 1987)

INTERPRETATION OF BECKER PENETRATION TESTS

PERFORMED AT RIRIE DAM IN 1986

Report Prepared for:

GEOTECHNICAL LABORATORY
WATERWAYS EXPERIMENT STATION
U.S. ARMY CORPS OF ENGINEERS

by

LESLIE F. HARDER, Jr.

August 1987

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1. INTRODUCTION

Background

Ririe Dam is situated on Willow Creek approximately 15 miles northeast of Idaho Falls, Idaho (Figure 1). Its principal function is to provide flood control in conjunction with irrigation, recreation, and wildlife habitat use. Figure 2 presents a typical cross-section of the embankment and foundation. As part of a seismic safety evaluation of Ririe Dam, the soils which make up the embankment's random zone and foundation are being studied for their potential to liquefy and lose strength during earthquake shaking.

For sandy soils, evaluations of liquefaction potential usually employ the Standard Penetration Test (SPT). This test consists of driving a standard 2-inch O.D. split spoon sampler into the bottom of a borehole for a distance of 18 inches. The SPT blowcount, or N value, is defined as the number of blows required to drive the sampler the last 12 inches. Based on the performance of sites which have sustained strong earthquake shaking, researchers have developed correlations between the cyclic strength of sands and the SPT blowcount (Seed et al. 1983, Seed et al. 1985).

Unfortunately, the large gravel and cobble particles present in the embankment's random zone and foundation precluded the use of the SPT at Ririe Dam. For the most part, any SPT blowcounts obtained would have given a misleadingly higher blowcount due to the 2-inch sampler simply bouncing off the large particles, or by having a large gravel particle block the opening of the sampler's shoe and resulting in the sampler being driven as a solid penetrometer. As an alternative to the

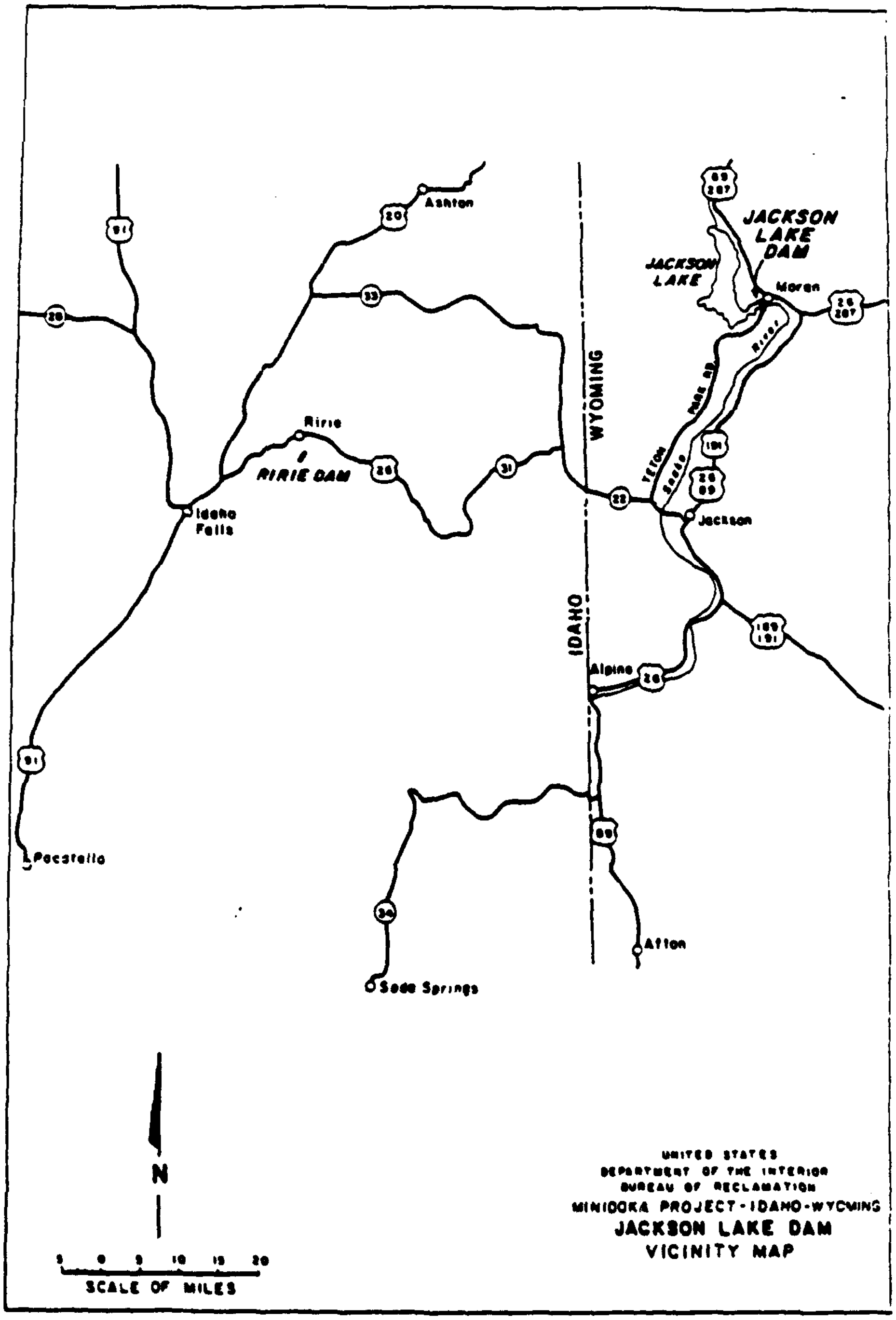

Figure 1: Location Map (after USBR)

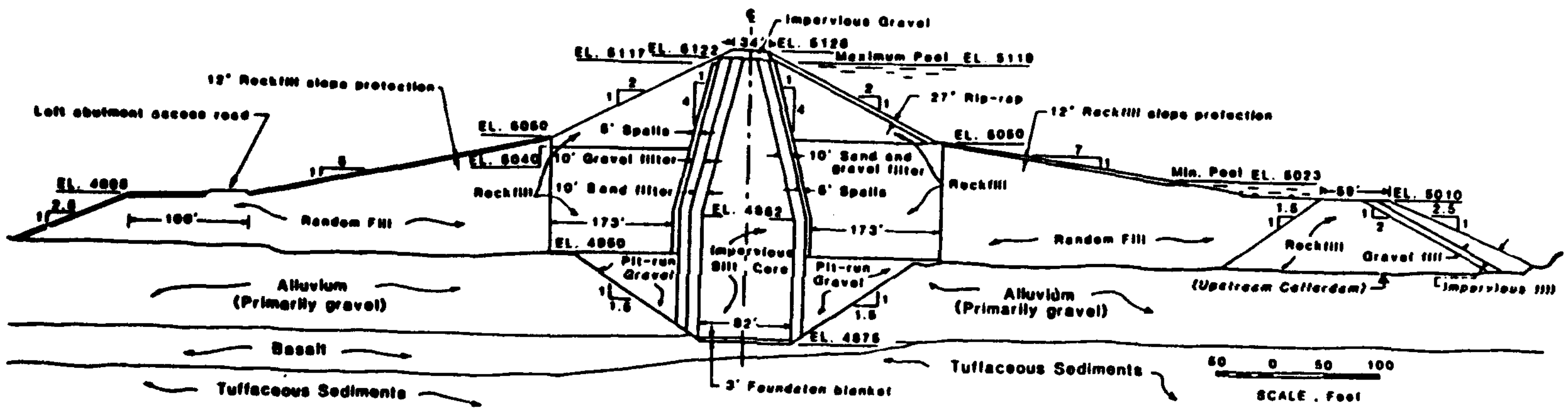

Figure 2: Typical Section of Ririe Dam (after USACE)

SPT, a larger penetration test was selected to explore the site. This test, known as the Becker Penetration Test (BPT), is generally used with a 6.6-inch O.D. double-walled casing and is driven into the ground with a diesel pile hammer. The Becker Penetration Test consists basically of counting the number of hammer blows required to drive the casing one foot into the ground. By counting the blows for each foot of penetration, a continuous record of penetration resistance can be obtained for an entire profile. The casing can be driven with an open bit and reverse air circulation to obtain disturbed samples (Figure 3), or with a plugged bit and driven as a solid penetrometer.

An exploration program was performed with a Becker Hammer drill rig at Ririe Dam in September 1986. A total of 18 open and plugged-bit soundings were conducted on the downstream berm and beyond the downstream toe of the embankment (Figure 4). In addition, 7 plugged-bit soundings were performed at Jackson Lake Dam in Wyoming in order to check the correlation between the Becker blowcounts and SPT blowcounts at a high-altitude location where good quality SPT data was available. The purpose of this report is to report on the explorations conducted and evaluate the Becker soundings at Ririe Dam in order to determine the cyclic strength of the deposits explored.

Scope of Work

The approach was to perform Becker soundings in the random zone and foundation alluvium, convert the Becker blowcounts into equivalent SPT blowcounts, and then use the correlation between SPT blowcount and liquefaction potential developed by Seed et al. (1985) to obtain an estimate of the cyclic strength. The conversion of Becker blowcounts into equivalent SPT blowcounts was performed using the procedures

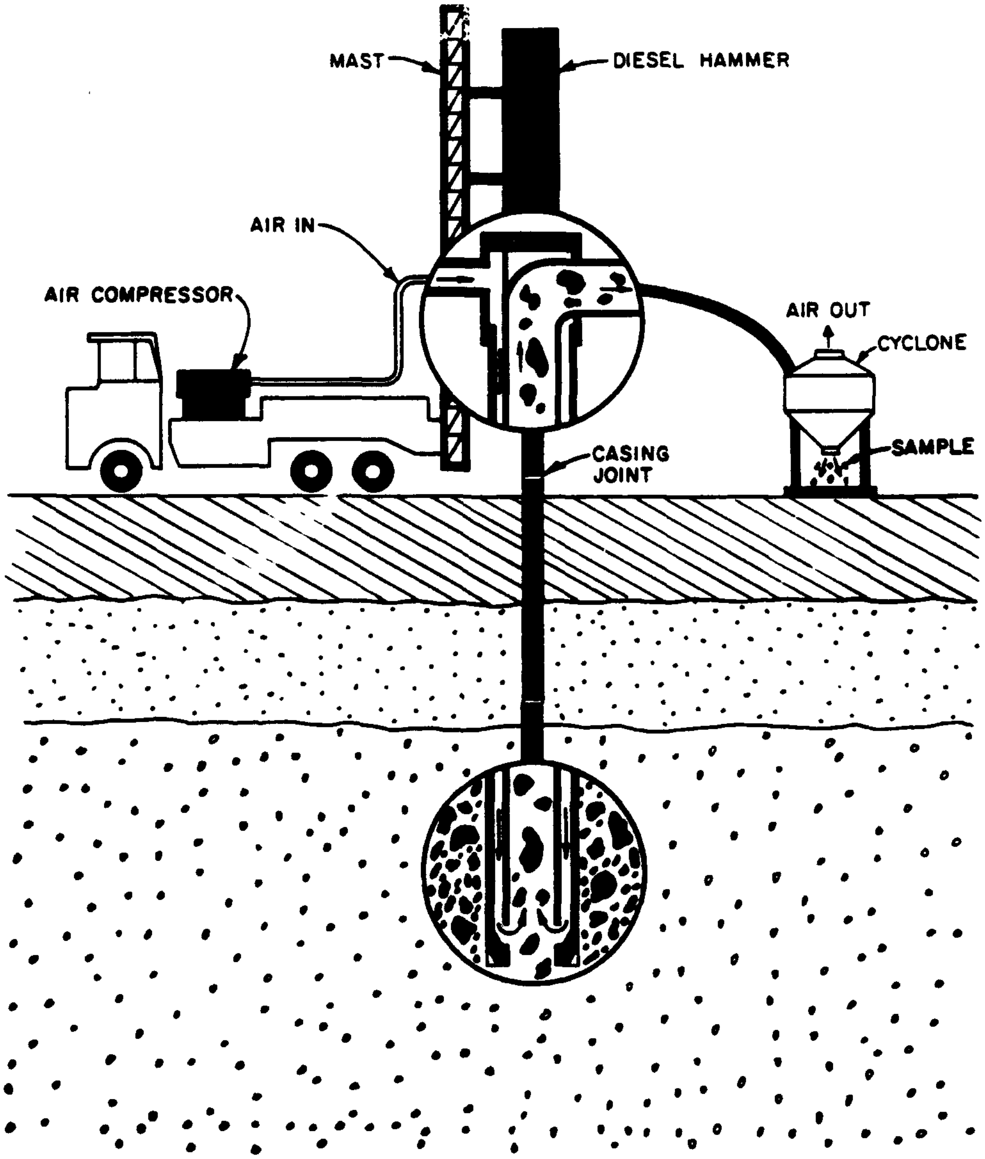

Figure 3: Schematic Diagram of Becker Sampling Operation
(after Harder and Seed, 1986)

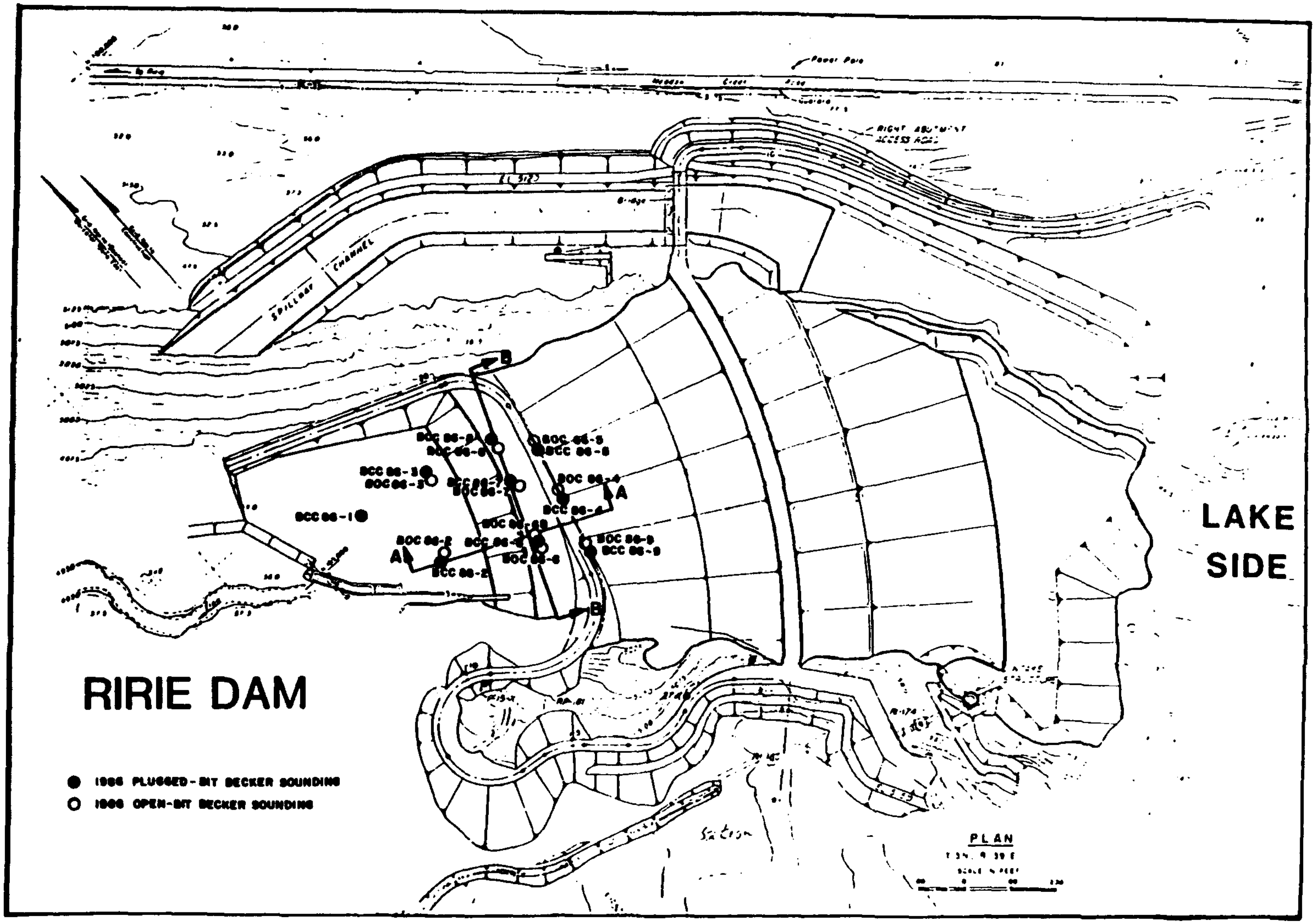

Figure 4: Plan View of Ririe Dam Showing Locations of Becker Soundings Performed in 1986

outlined by Harder and Seed (1986). Because the Becker Penetration Test is a non-standard test, and because the effect of overburden pressure on blowcount had to be accounted for, there were several intermediate steps prior to the final determination of cyclic strength. In summary, the steps of the correction process are presented below:

1. Because the diesel hammer can be run at a wide variety of combustion conditions, all of the Becker Penetration Test blowcounts were corrected to blowcounts obtained with a standard set of constant combustion conditions (Section 2).

2. Because the diesel hammer energy and the monitoring of that energy is affected by atmospheric pressure, corrections for elevation have to be made during the hammer energy determination (Section 2).

3. Because the hammer energy is so variable and because the correlation between Becker blowcounts and SPT blowcounts was developed for sea level sites, it was decided to check the equivalent SPT blowcounts determined from the Becker Penetration Test against actual SPT blowcounts available in sandy and silty soils at Jackson Lake Dam (Section 3).

4. Using the correlation developed by Harder and Seed (1986), the corrected Becker blowcounts were converted into equivalent SPT blowcounts (Section 4).

5. Using preliminary estimates of effective stress, the equivalent SPT values from different depths and stress levels were normalized to those that would have been obtained in the same material under level ground conditions with an effective overburden stress of 1 tsf (Section 4).

6. Using the correlation developed by Seed et al. (1985), the normalized equivalent SPT blowcounts were used to obtain estimates of cyclic strength for the soils within the dam's random zone and foundation (Section 5).

7. A summary of results is also presented (Section 6).

In addition, Appendices A and D present the drill hole logs for the 1986 Becker soundings performed at Jackson Lake Dam and Ririe Dam. Appendices B and E show plots of corrected bounce pressure vs. uncorrected Becker blowcount data obtained from the two dams. Appendices C and F present calculation tables for the conversion of uncorrected Becker blowcounts into equivalent SPT blowcounts. Appendix G contains slides of Ririe Dam and recovered samples photographed during the September 1986 explorations.

The basic data used in this report were obtained during field work at Jackson Lake Dam, Wyoming and Ririe Dam, Idaho between September 15, 1986 and September 27, 1986. Data relating to SPT test results at Jackson Lake Dam were provided by Karl Wirkus and Derrick Roser of the United States Bureau of Reclamation. Data concerning the geometry and previous explorations made at Ririe Dam were provided by Dave Sykora of the Waterways Experiment Station, United States Army Corps of Engineers. Data concerning water levels of the reservoir and within piezometers at Ririe Dam were provided by Jim Stevenson of the United States Bureau of Reclamation at Ririe Dam.

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2. METHOD FOR DETERMINATION OF EQUIVALENT SPT BLOWCOUNTS

Corrections to Becker Penetration Resistance for Combustion Energy

Constant energy conditions are not a feature of the double-acting diesel hammers used in the Becker Penetration Test. One reason for this is that the energy is dependent upon combustion conditions; thus anything that affects combustion, such as fuel quantity, fuel quality, air mixture and pressure all have a significant effect on the energy produced. Combustion efficiency is operator-dependent because the operator controls a variable throttle which affects how much fuel is injected for combustion. On some rigs, the operator also controls a rotary blower which adds additional air to the combustion cylinder during each stroke. This additional air is thought to better scavenge the cylinder of burnt combustion gases and has been found to produce higher energies (Reference 1).

To monitor the level of energy produced by the diesel hammer during driving, use is made of the bounce chamber pressure. For the ICE Model 180 diesel hammers used on the Becker drill rigs, the top of the hammer is closed off to allow a smaller stroke and a faster driving rate. At the top, trapped air in the compression cylinder and in a connected bounce chamber acts as a spring. The amount of potential energy within the ram at the top of its stroke can be estimated by measuring the peak pressure induced in the bounce chamber. Although calibration charts between potential energy and bounce chamber pressure are available from the manufacturer of the hammer, studies by Harder and Seed (1986) have shown that they are unable to predict the change in Becker blowcount for different levels of bounce chamber pressure.

Another reason why the energy is not a constant with the Becker Hammer Drill is that the energy developed is dependent on the blowcount of the soil being penetrated. As blowcounts decrease, the displacement of the casing increases with each stroke. With increasing casing displacement, a larger amount of energy from the expanding combustion gases is lost to the casing movement rather than being used to raise the ram for the next stroke. Thus, as blowcounts decrease, the energy developed by the hammer impact on subsequent blows also decreases. Conversely, if the blowcounts increase, then there is less casing displacement per blow and more of the combustion energy is directed upward in raising the ram for the next stroke. Figure 5 shows a curve illustrating a typical relationship between Becker blowcounts and bounce chamber pressure for constant combustion conditions (Reference 1). This curve is designated as a constant combustion rating curve and is just one member of a family of such curves that can be produced by a given drill rig and hammer.

Studies by Harder and Seed (1986) have shown that diesel hammer combustion efficiency significantly affects the Becker blowcount. Presented in Figure 6 are typical results obtained for different combustion efficiencies. In the upper plot, three combustion rating curves representing three different combustion efficiencies are shown. With different combustion conditions, the resulting blowcounts from tests performed in the same materials can be radically different. Consequently, tests in the same material at a depth of 40 feet can give a Becker blowcount of 14 when the hammer is operated at high combustion efficiency (throttle and blower on full), but give blowcounts of 26 and 50 at succeeding reductions of combustion energy.

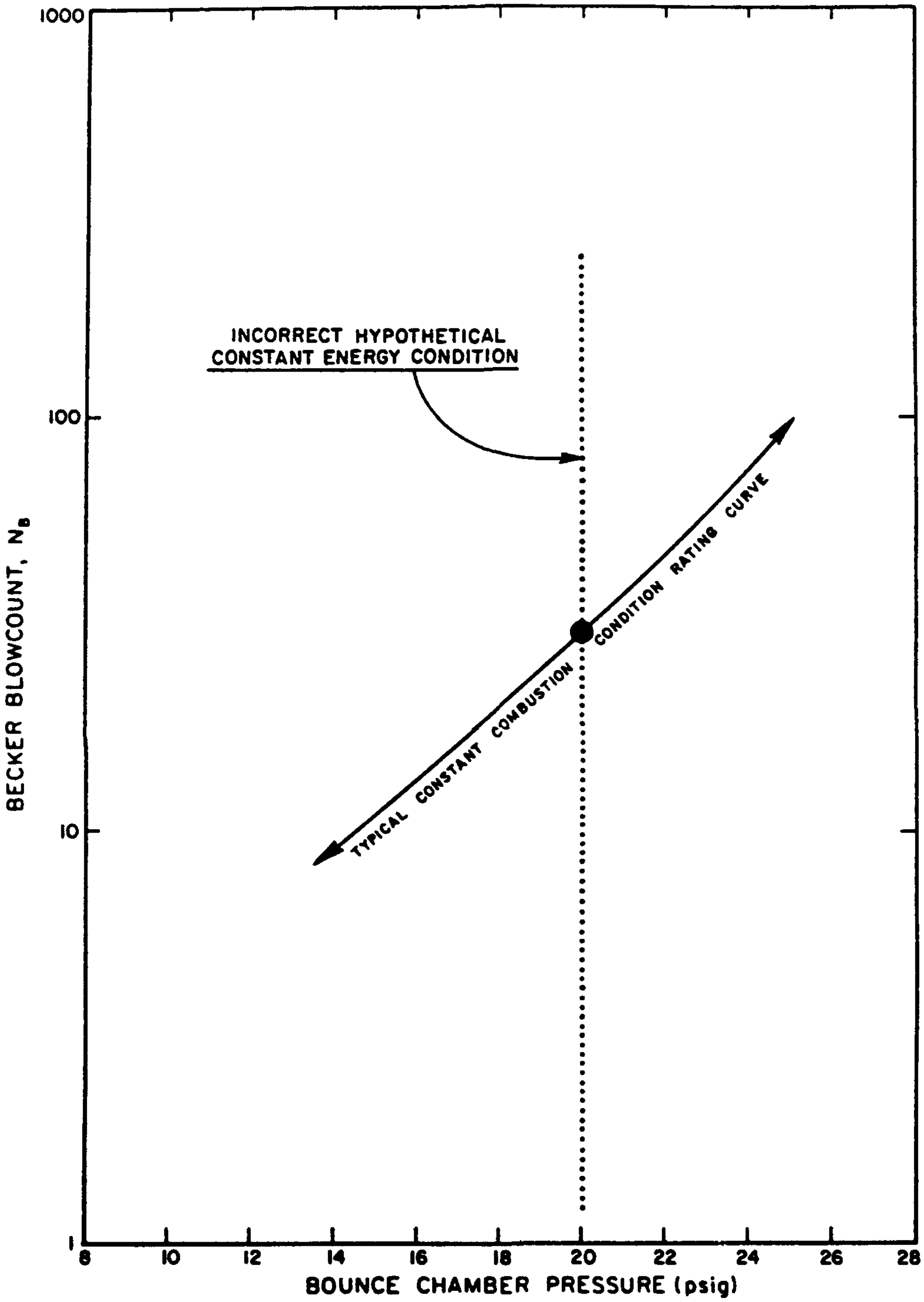
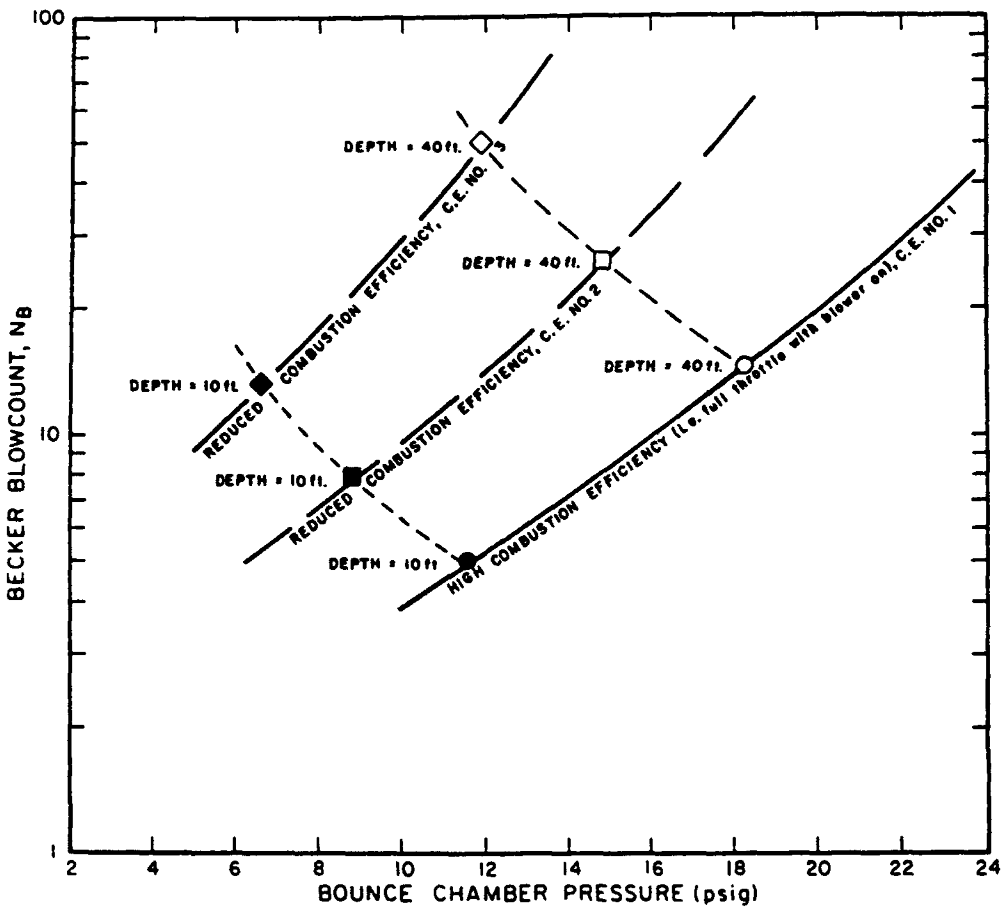


Figure 5: Typical Relationship Between Becker Blowcount and Bounce Chamber Pressure (after Harder and Seed, 1986)



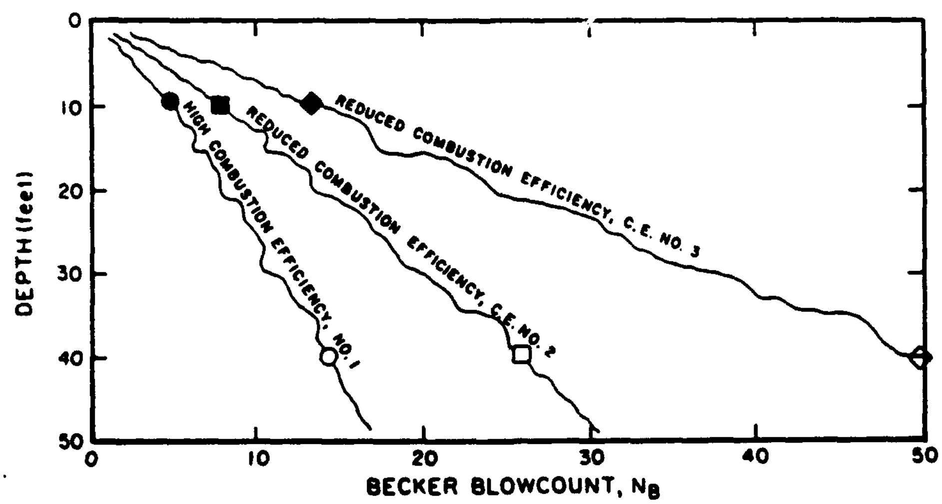


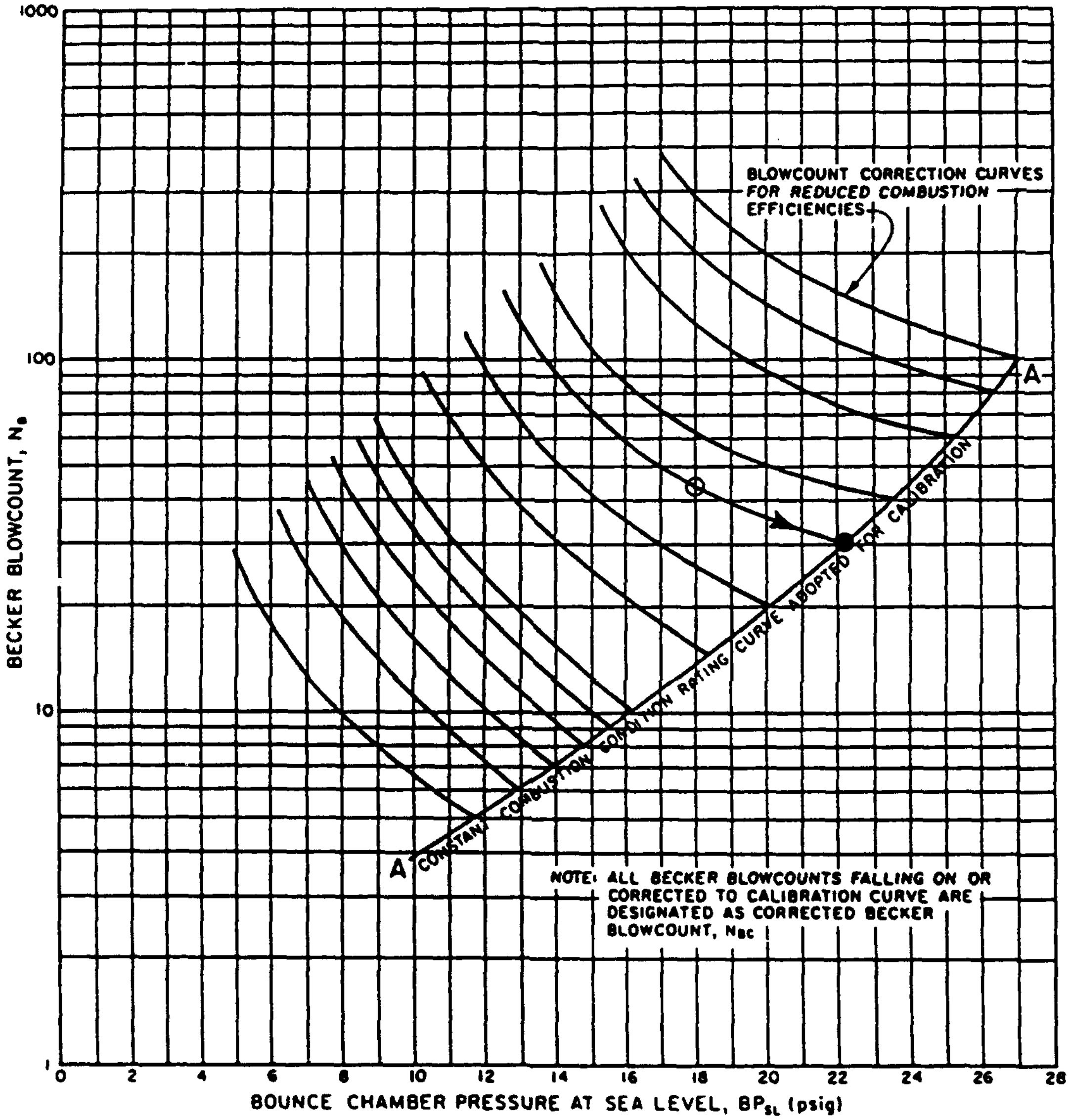
Figure 6: Idealization of How Diesel Hammer Combustion Efficiency Affects Becker Blowcounts (after Harder and Seed, 1986)

To account for combustion effects, it is necessary to adopt a standard combustion efficiency and make corrections to the blowcount for different combustion conditions. For the corrections of the 1986 Jackson Lake Dam and Ririe Dam data, the curve marked in Figure 7 with the symbols AA was selected. This curve was chosen because it was the curve used by Harder and Seed (1986) to correct Becker data before correlating Becker blowcounts to SPT blowcounts. Also shown in Figure 6 are correction curves that are used to reduce measured Becker blowcounts to corrected Becker blowcounts when reduced combustion levels were employed during testing.

To use the correction curves, it is simply necessary to locate each uncorrected test result on the chart shown in Figure 7, using both the uncorrected blowcount and the bounce chamber pressure, and then follow the correction curves down to the standard rating curve AA, to obtain the corrected Becker blowcount, denoted as N_{BC}. For example, if the uncorrected blowcount was 44 and it was obtained at sea level with a bounce chamber pressure of 18 pounds per square inch-gauge (psig), then the corrected Becker blowcount would be 30 (Figure 7).

Correction for Atmospheric Pressure

The pressure monitored within the bounce chamber is used as an indicator of the amount of energy being produced by the diesel hammer during driving. However, for different atmospheric pressures, a different bounce chamber pressure will result for the same amount of hammer energy. Because the combustion rating curves and correlations have been developed for atmospheric pressures comparable to standard sea level pressure (14.7 psia), it is necessary to correct the bounce chamber data when tests are performed with atmospheric pressures



O EXAMPLE MEASURED BLOWCOUNT, N_B

● EXAMPLE CORRECTED BLOWCOUNT, N_{BC}

Figure 7: Correction Curves Adopted to Correct Becker blowcounts to Constant Combustion Curve Adopted for Calibration (after Harder and Seed, 1986)

significantly different from 14.7 psia. For data taken where the atmospheric pressure is less than about 14.7 psia, this correction takes the form of raising the measured bounce chamber pressure to equivalent sea level bounce pressures. The amount of increase is determined by using theoretical ratios of impact kinetic energy (see Reference 1). For the Becker soundings performed at Jackson Lake Dam and Ririe Dam, it is necessary to correct the measured bounce chamber pressures since these two dams are located at relatively high elevations and low atmospheric pressures. The approximate elevations and atmospheric pressures for the two sites are listed below:

Site	Elevation (feet)	Atmospheric Pressure (psia)
Jackson Lake Dam	6800	11.4
Ririe Dam	5000	12.3

Shown in Tables 1 and 2 are the bounce chamber pressure corrections required for the data obtained at Jackson Lake Dam and Ririe Dam. In general, the bounce chamber measurements at Jackson Lake Dam required an increase of about 4 to 6 psi and the measurements made at Ririe Dam required an increase of about 3 to 5 psi in order to be corrected to equivalent sea level pressures.

Table 1: Bounce Chamber Pressure Corrections for Atmospheric Pressure for Data Obtained at Jackson Lake Dam.

Measured Bounce Chamber Pressure (psig)	Atmospheric Pressure (psia)	Equivalent Sea Level Bounce Chamber Pressure (psig)
7	11.4	11.2
8	11.4	12.5
9	11.4	13.8
10	11.4	15.1
11	11.4	16.3
12	11.4	17.5
13	11.4	18.2
14	11.4	20.0
15	11.4	21.1
16	11.4	22.3
17	11.4	23.5
18	11.4	24.6

Table 2: Bounce Chamber Pressure Corrections for Atmospheric Pressure for Data Obtained at Ririe Dam.

Measured Bounce Chamber Pressure (psig)	Atmospheric Pressure (psia)	Equivalent Sea Level Bounce Chamber Pressure (psig)
6	12.3	8.8
7	12.3	10.0
8	12.3	11.2
9	12.3	12.4
10	12.3	13.5
11	12.3	14.7
12	12.3	15.9
13	12.3	17.0
14	12.3	18.2
15	12.3	19.3
16	12.3	20.4
17	12.3	21.6
18	12.3	22.7
19	12.3	23.8
20	12.3	24.9
21	12.3	26.0
22	12.3	27.1
23	12.3	28.2
24	12.3	29.3

Conversion of Becker Blowcounts into Equivalent SPT Blowcounts

The correlation curve and the data used by Harder and Seed (1986) to generate the relationship between corrected Becker blowcounts and equivalent SPT blowcounts are presented in Figure 8. As detailed above, the corrections to measured Becker data that are required before using this correlation are as follows:

1. Correction of measured data for atmospheric pressure.
2. Correction of measured data for combustion effects.

After these two corrections were made, all of the 1986 Jackson Lake Dam and Ririe Dam Becker data were converted into equivalent SPT blowcounts, denoted by the symbol N_{60}.

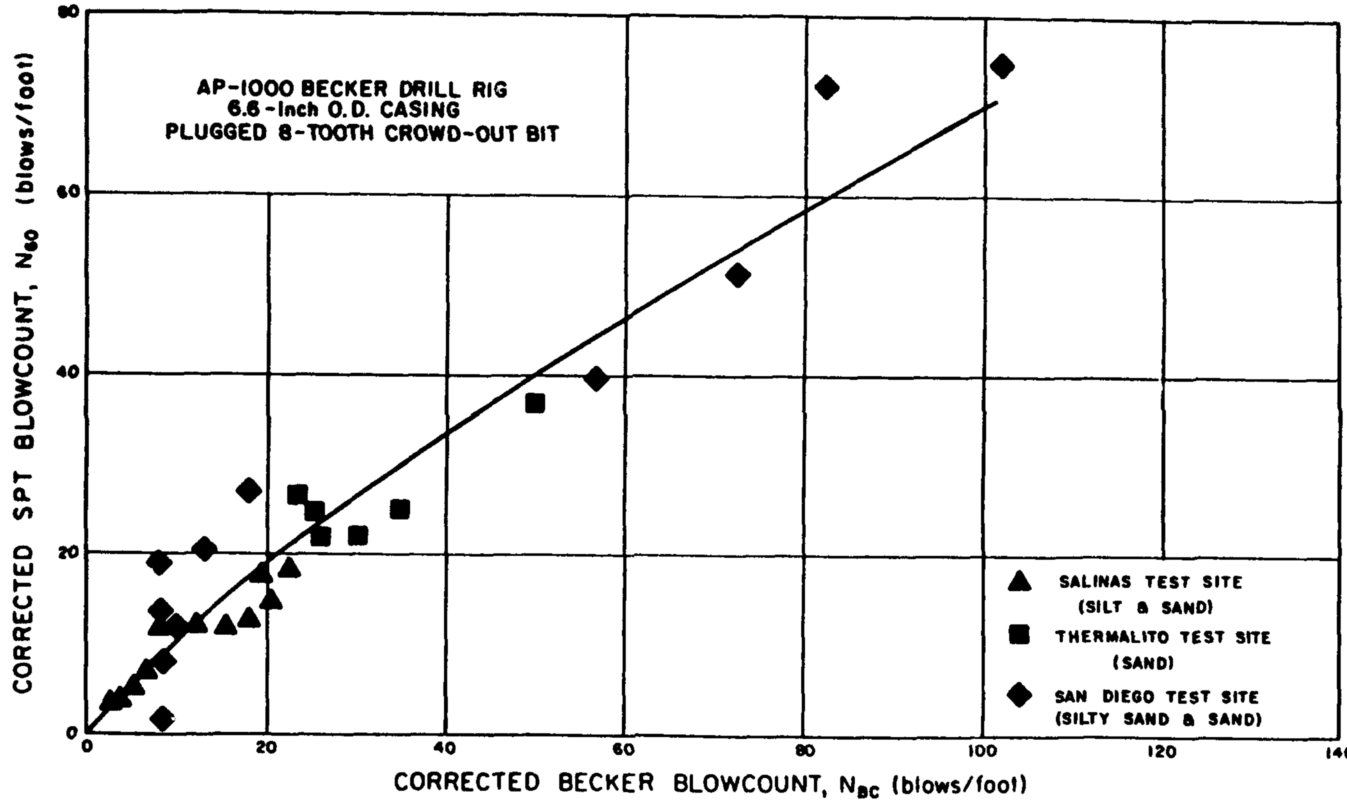


Figure 8: Correlation Between Corrected Becker and SPT Blowcount (after Harder and Seed, 1986)

3. BECKER EXPLORATIONS PERFORMED AT JACKSON LAKE DAM

General

The Becker drill rig employed for the explorations at Ririe Dam is a model AP-1000 Becker drill rig manufactured by Drill Systems, Ltd. and owned by Becker Drills, Inc. It is identified as Rig No. 57 by Becker Drills and is the same rig used by Harder and Seed (1986) to develop the correlation between Becker blowcounts and SPT blowcounts. However, because that correlation was made at essentially sea level atmospheric conditions, and the because the energy corrections can be significant in magnitude, it was decided to perform a local check between corrected Becker blowcounts and corrected SPT blowcounts at Jackson Lake Dam. Jackson Lake Dam was adopted as a test location for the following reasons:

1. The United States Bureau of Reclamation (USBR) was performing remedial work at Jackson Lake Dam including the removal of embankment material and the dynamic compaction of the underlying foundation soils. As part of this work, the USBR had made a number of high quality SPT explorations in the various foundation soils.

2. The foundation at Jackson Lake Dam contained a significant amount of sand and silt layers. Sands and silts are appropriate materials to conduct correlations between Becker and SPT blowcounts.

3. The USBR was gracious enough to allow Becker soundings at locations where SPT data had already been obtained and was willing to share the SPT information.

4. Jackson Lake Dam was relatively close to Ririe Dam (Figure 1) and was approximately on the travel route of the Becker drill rig.

Seven 6.6-inch O.D. plugged-bit Becker soundings were performed at three test sites at Jackson Lake Dam on September 16, 1986. The work was performed as follows:

1. Sector H - Three plugged-bit Becker soundings at Sector H. Sector H was a location where the embankment was removed and was awaiting treatment by deep dynamic compaction.

2. Sector A - One plugged-bit Becker sounding at Sector A. Sector A was a location where the embankment was removed and had already been treated using deep dynamic compaction. However, because the SPT data available at this site was obtained prior to treatment, the results from this site are not appropriate to check the correlation between Becker and SPT blowcounts.

3. Untreated Pad A - Three plugged-bit Becker sounding at an untreated area of Pad A. Pad A is an area located in the foundation near the downstream toe of the embankment. Pad A was used previously as a test site using compaction piles to densify the sands and silts in the foundation. The three Becker soundings were performed in an area of Pad A which was not treated.

Corrections for USBR SPT Test Procedures at Jackson Lake Dam

Test procedures can significantly affect the results of SPT tests. Consequently, standard procedures and corrections for non-standard procedures have been developed (see Reference 8). The standard procedures include using mud-filled rotary boreholes, upward deflecting or tricone drill bits with diameters less than 5 inches, and standard samplers with 2.0-inch O.D. and 1.38-inch constant I.D. The USBR SPT tests performed at the three Jackson Lake Dam test sites all seem to have used the above test procedures.

Another significant test procedure is the amount of hammer energy that is delivered to the sampling rods during the SPT test. The

standard that has been adopted by Seed et al. (1985) for use in liquefaction evaluations is 60 percent of the theoretical free-fall energy of a 140-lb hammer falling 30 inches. The SPT blowcount that would be produced using this energy level is denoted as N_{60}. The SPT tests performed in 1984 at the untreated section of Pad A used a 140-lb. safety hammer and this was believed to have delivered approximately 60 percent of the theoretical free-fall energy to the drill rods (References 4 and 8). Consequently, the SPT data obtained in the untreated area of Pad A needed no corrections to be converted into N_{60} values. However, the SPT data obtained in early 1986 in Sectors A and H employed SPT hammer/release systems which were measured delivering an average of about 40 percent of the theoretical free-fall energy (Reference 4). Accordingly, the measured SPT blowcounts obtained in Sectors A and H were multiplied by the ratio of 40/60 to obtain N_{60} blowcounts in these areas (see Reference 8).

Results Obtained at Sector H

Figure 9 shows a plan view of Sector H illustrating the physical relationship between the nearby SPT borings and the three Becker soundings performed in this area. In general, the combustion efficiency developed by the Becker diesel hammer at this site was similiar to the constant combustion rating curve adopted for standardization (Curve AA in Figure 7, see Figure B-1 in Appendix B). Figure 10 presents the measured Becker blowcounts together with the equivalent SPT N_{60} values obtained using the procedures outlined in Section 2 and Reference 1. Figure 11 presents a comparison of corrected SPT and Becker-derived equivalent N_{60} values plotted as a function of elevation. In general, the correlation between SPT and

JACKSON LAKE DAM
SECTOR H

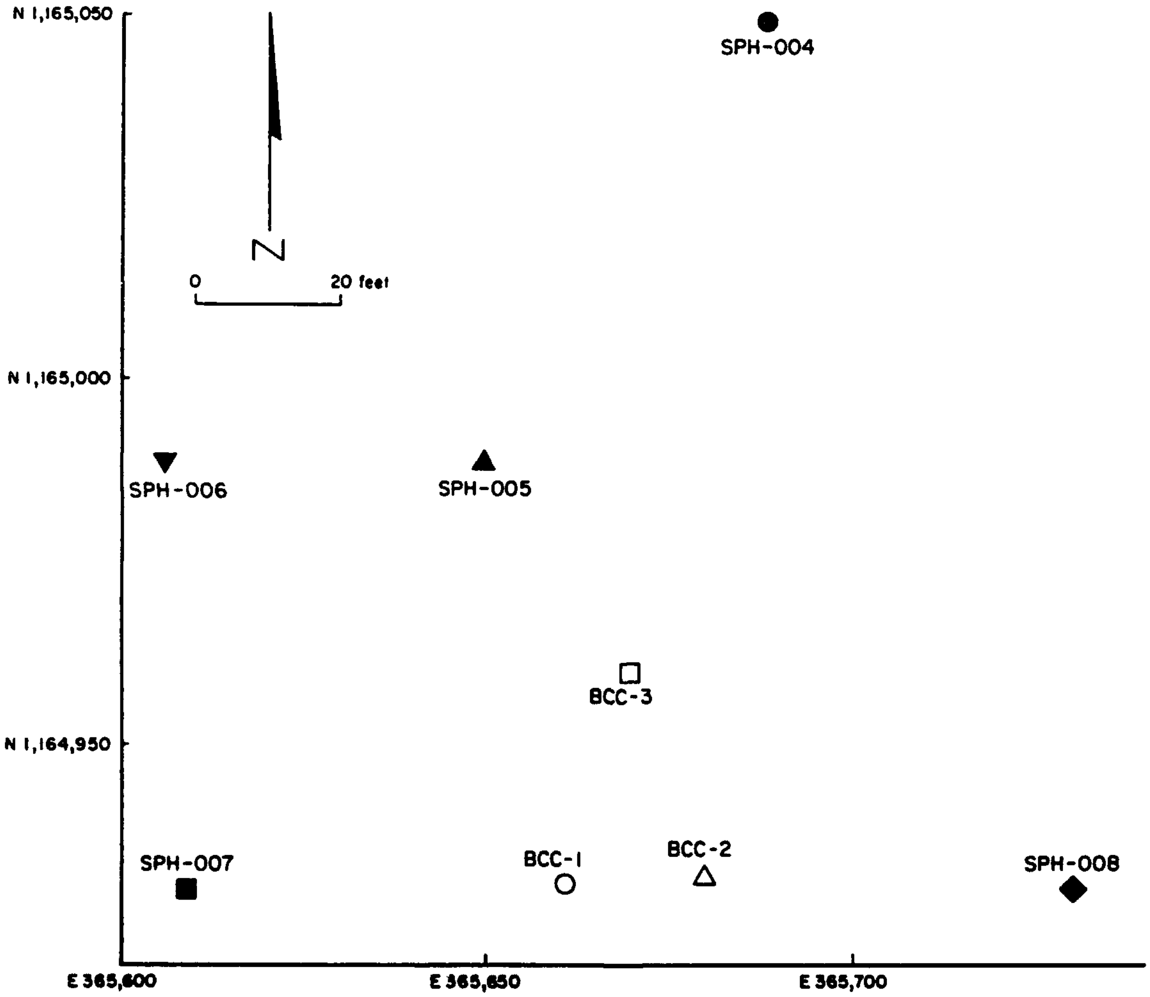


Figure 9: Plan View of Sector H Test Site at Jackson Lake Dam

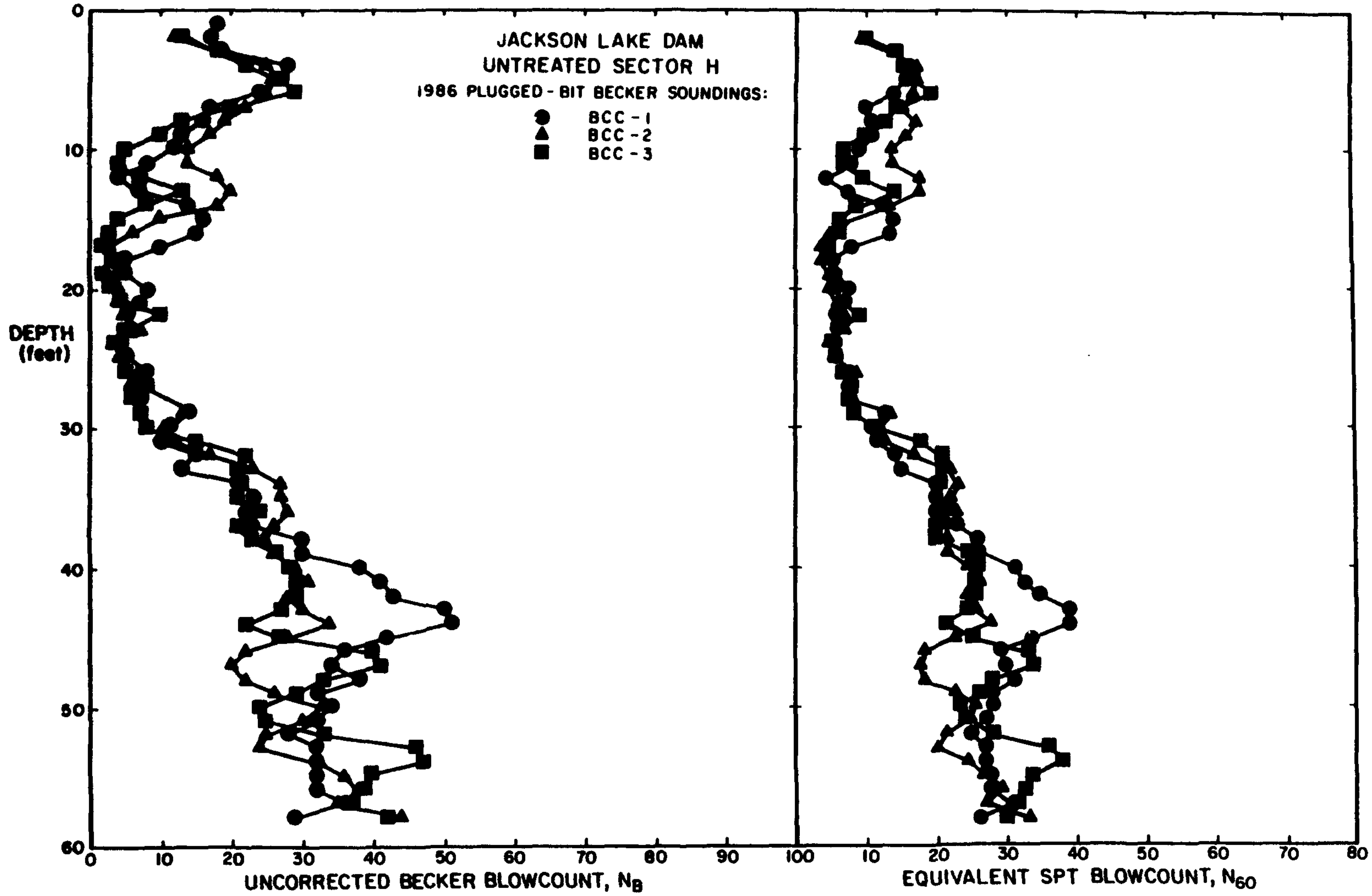


Figure 10: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Sector H Test Site at Jackson Lake Dam

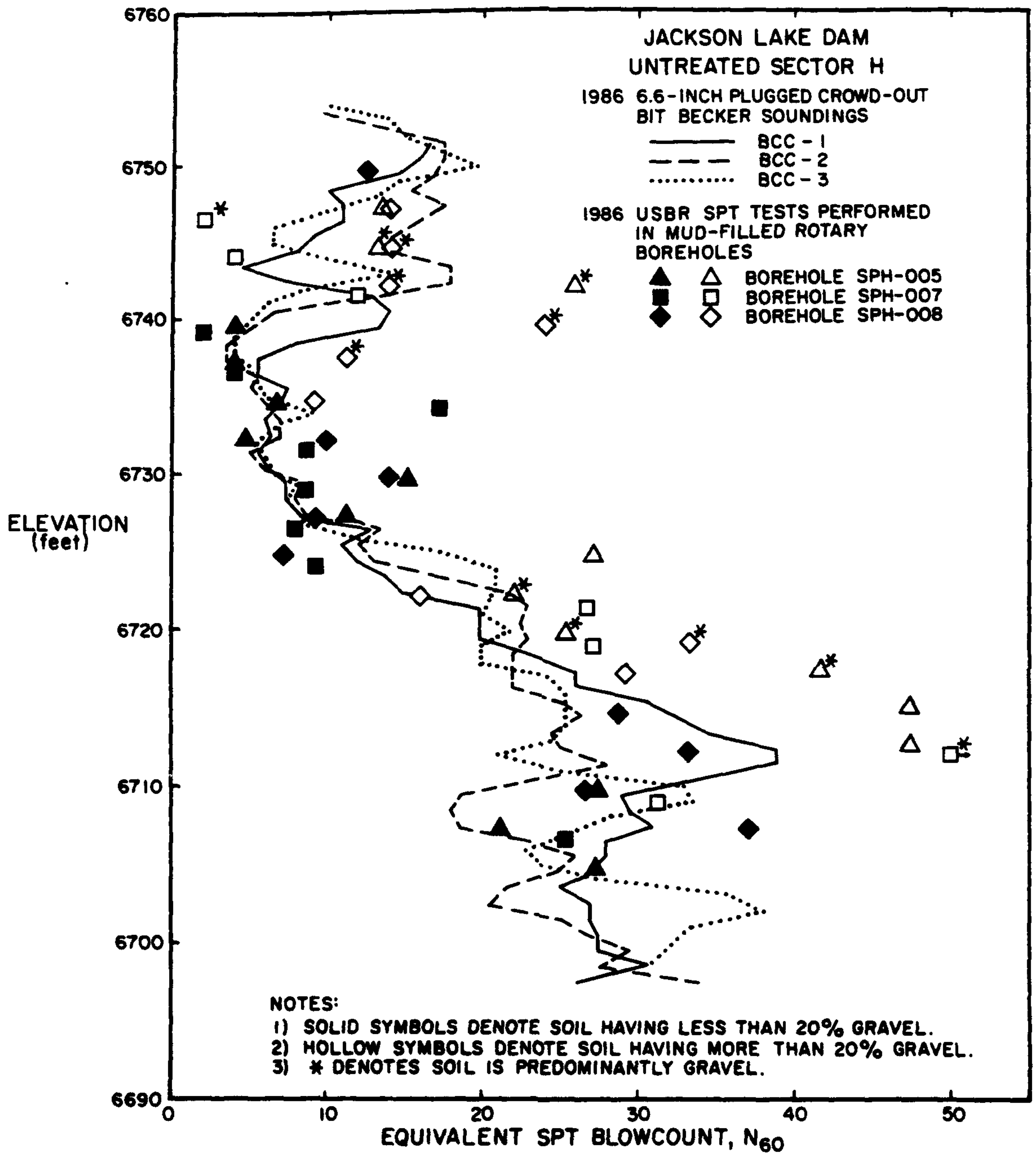


Figure 11: Comparison of Becker Equivalent SPT Blowcounts with SPT Blowcounts Obtained at Sector H Test Site at Jackson Lake Dam

Becker equivalent N_{60} blowcounts is excellent:

a. Within elevation intervals 6704-6715 and 6724-6739 feet where the soil is principally sand and silt without gravel, both the SPT and Becker equivalent N_{60} values have the same general magnitude, trend, and spread.

b. Within elevation intervals 6715-6723 and 6740-6748 feet where the soil is principally gravelly, the SPT blowcounts are generally 50 to 100 percent higher than the Becker equivalent N_{60} values. This trend has been observed in other test programs and is presumably due to the fact that the small 2-inch O.D. SPT sampler is simply bouncing off large gravel particles at times giving unrepresentatively high blowcounts.

Results Obtained at Sector A

Figure 12 shows a plan view of Sector A illustrating the physical relationship between the nearby SPT borings and the one Becker sounding performed in this area. In general, the combustion efficiency developed by the Becker diesel hammer at this site was similiar to the constant combustion rating curve adopted for standardization (Curve AA in Figure 7, see Figure B-2 in Appendix B). Figure 13 presents the measured Becker blowcounts together with the equivalent SPT N_{60} values obtained using the procedures outlined in Section 2 and Reference 1. Figure 14 presents a comparison of corrected SPT and Becker-derived equivalent N_{60} values plotted as a function of elevation. Because of the predominantly gravelly nature of the soil layers and because of the fact that the SPT tests were performed prior to dynamic compaction and the Becker soundings were performed after compaction, the results obtained at this site are not appropriate for

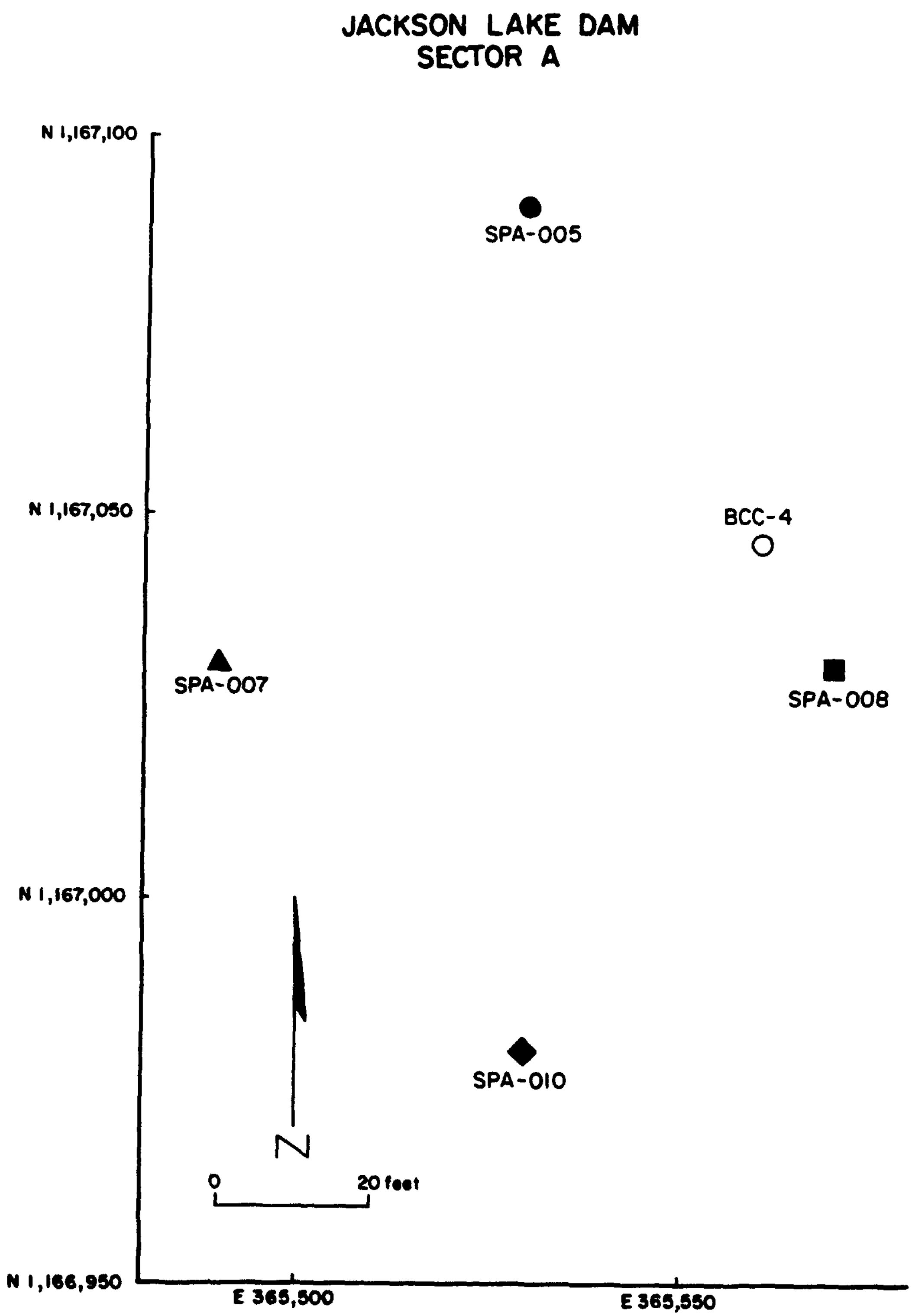


Figure 12: Plan View of Sector A Test Site at Jackson Lake Dam

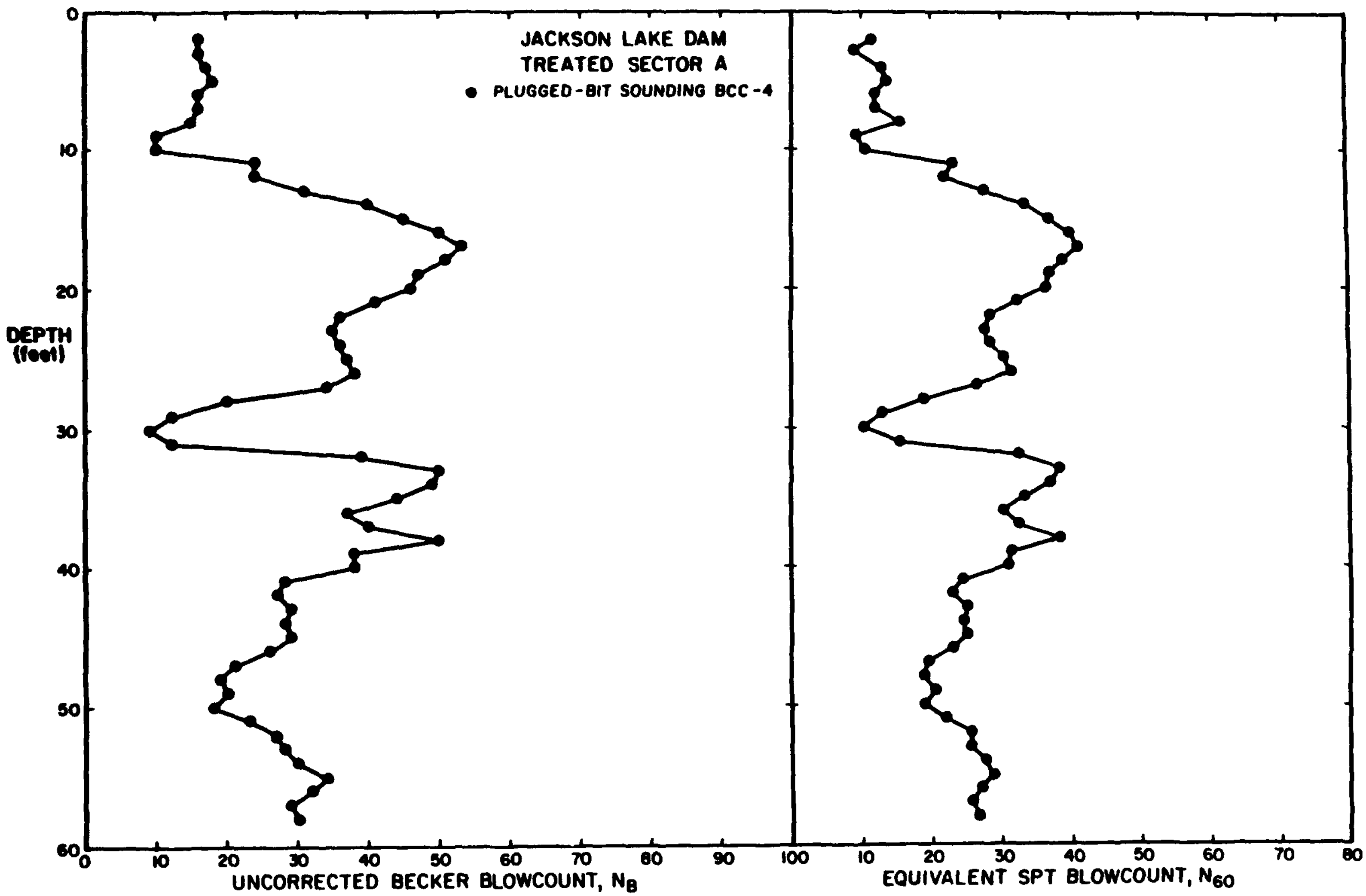


Figure 13: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Sector A Test Site at Jackson Lake Dam

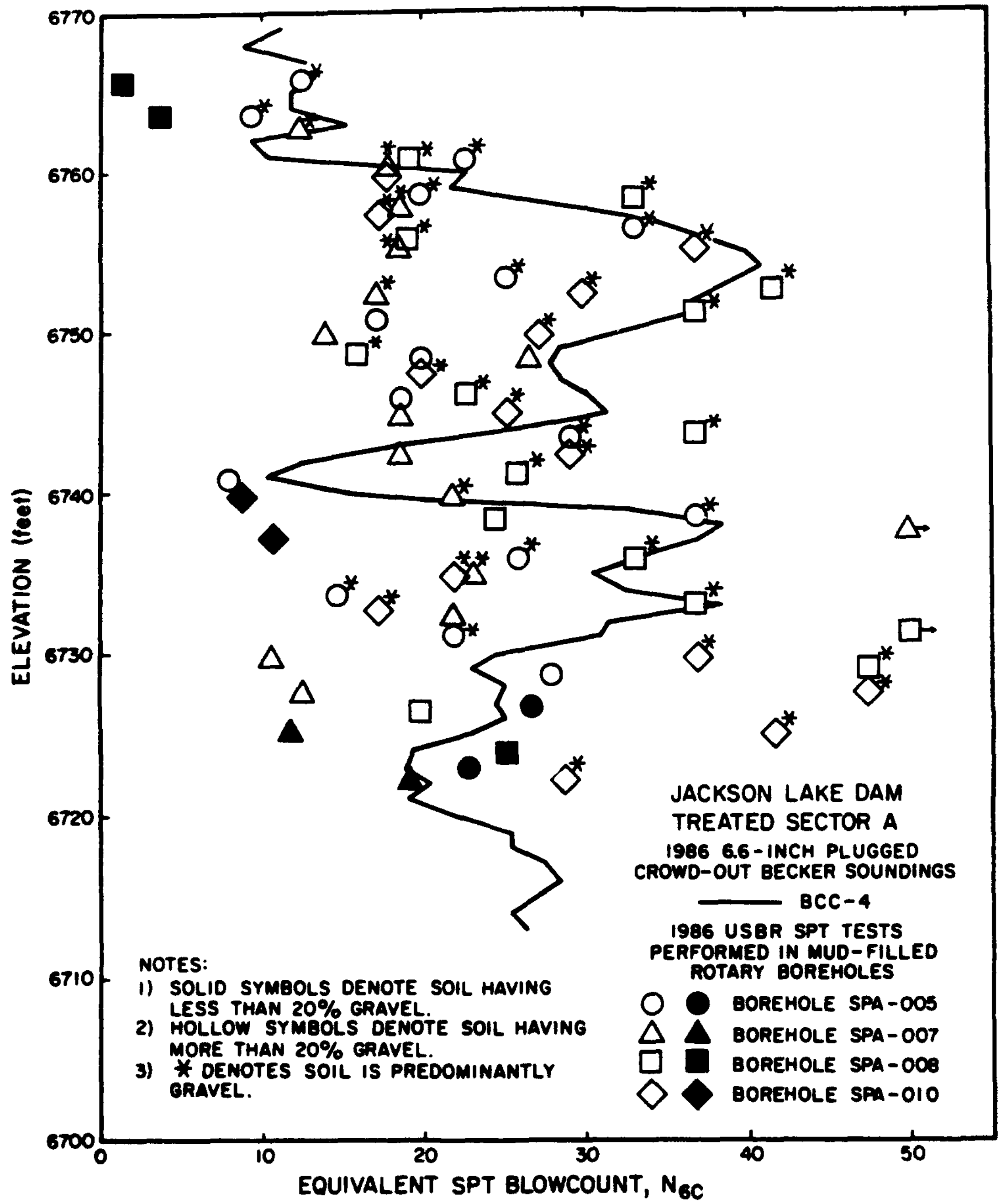


Figure 14: Comparison of Becker Equivalent SPT Blowcounts with SPT Blowcounts Obtained at Sector A Test Site at Jackson Lake Dam

checking the correlation between SPT and Becker blowcounts. About all that can be determined from Figure 14 is that the dynamic compaction process seems to have significantly improved the soil above Elevation 6730 feet at this site.

Results Obtained at Untreated Pad A

Figure 15 shows a plan view of untreated Pad A illustrating the physical relationship between the nearby SPT borings and the three Becker soundings performed in this area. In general, the combustion efficiency developed by the Becker diesel hammer at this site was slightly higher than the constant combustion rating curve adopted for standardization (Curve AA in Figure 7, see Figure B-3 in Appendix B). Figure 16 presents the measured Becker blowcounts together with the equivalent SPT N_{60} values obtained using the procedures outlined in Section 2 and Reference 1. Figure 17 presents a comparison of corrected SPT and Becker-derived equivalent N_{60} values plotted as a function of elevation. In general, the correlation between SPT and Becker equivalent N_{60} blowcounts is rather mixed:

a. Between elevations 6713 and 6720 feet, the correlation between SPT and Becker-derived equivalent N_{60} blowcounts is good. Within the sand and silt in this interval, both penetrometers register the same general magnitude of resistance with the Becker blowcounts showing less scatter than the SPT data.

b. Between elevations of 6690 and 6713 feet, the correlation between SPT and Becker-derived equivalent N_{60} blowcounts is poor. In general, actual SPT N_{60} data averages to about 8 blows per foot and the Becker data predicts equivalent blowcounts between 20 and 30, approximately three times higher than the actual SPT N_{60} data.

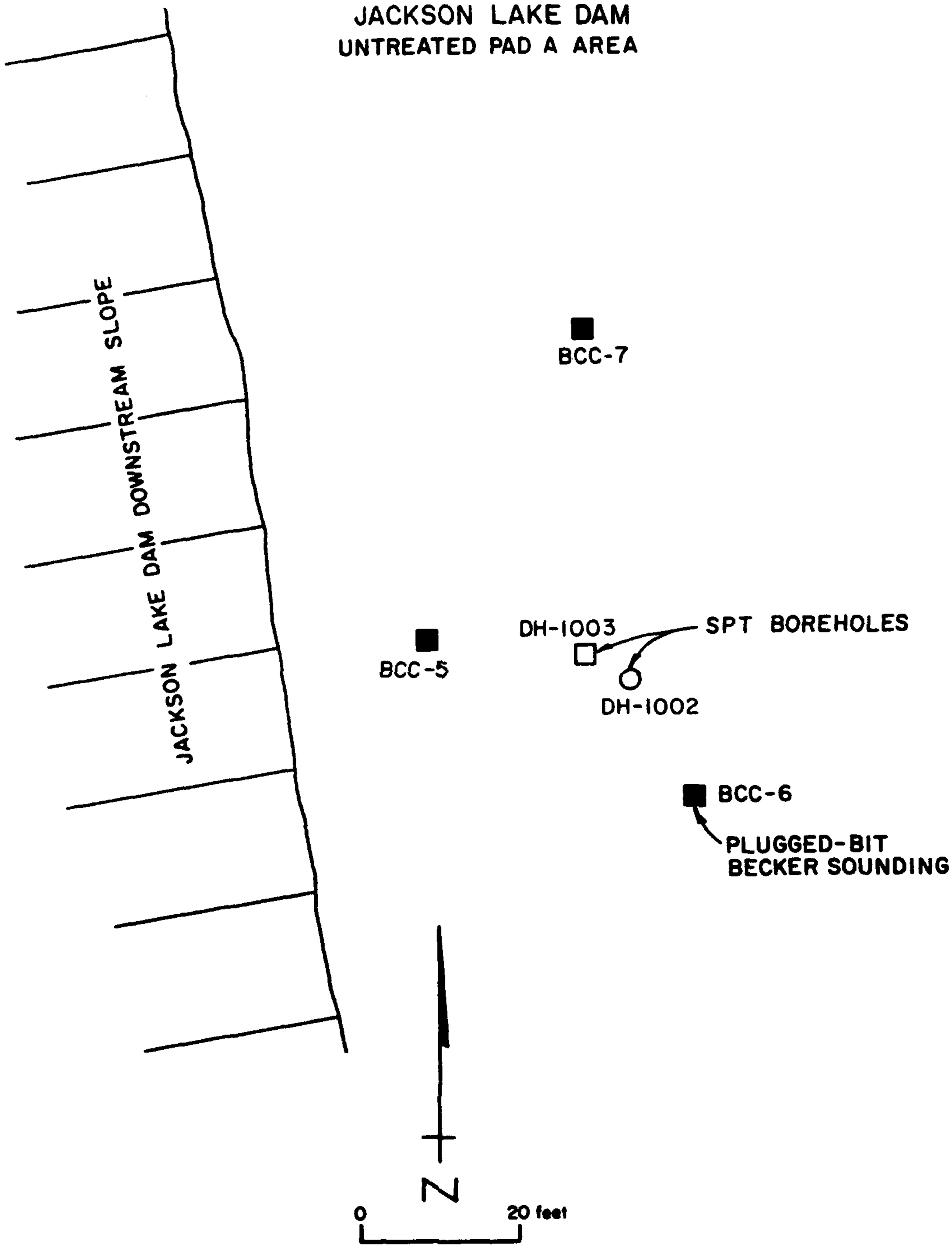


Figure 15: Plan View of Pad A Test Site at Jackson Lake Dam

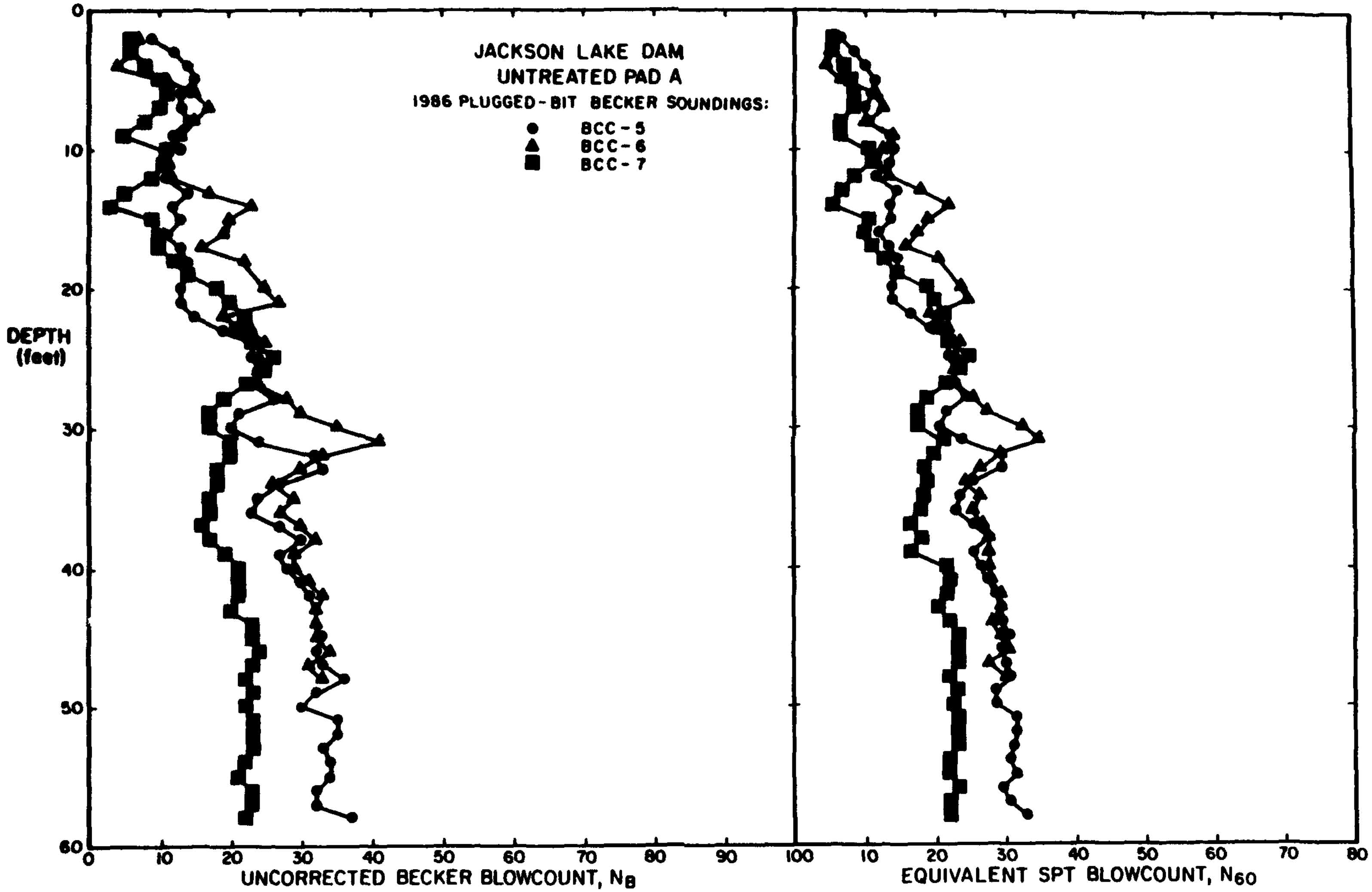


Figure 16: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Untreated Pad A Test Site at Jackson Lake Dam

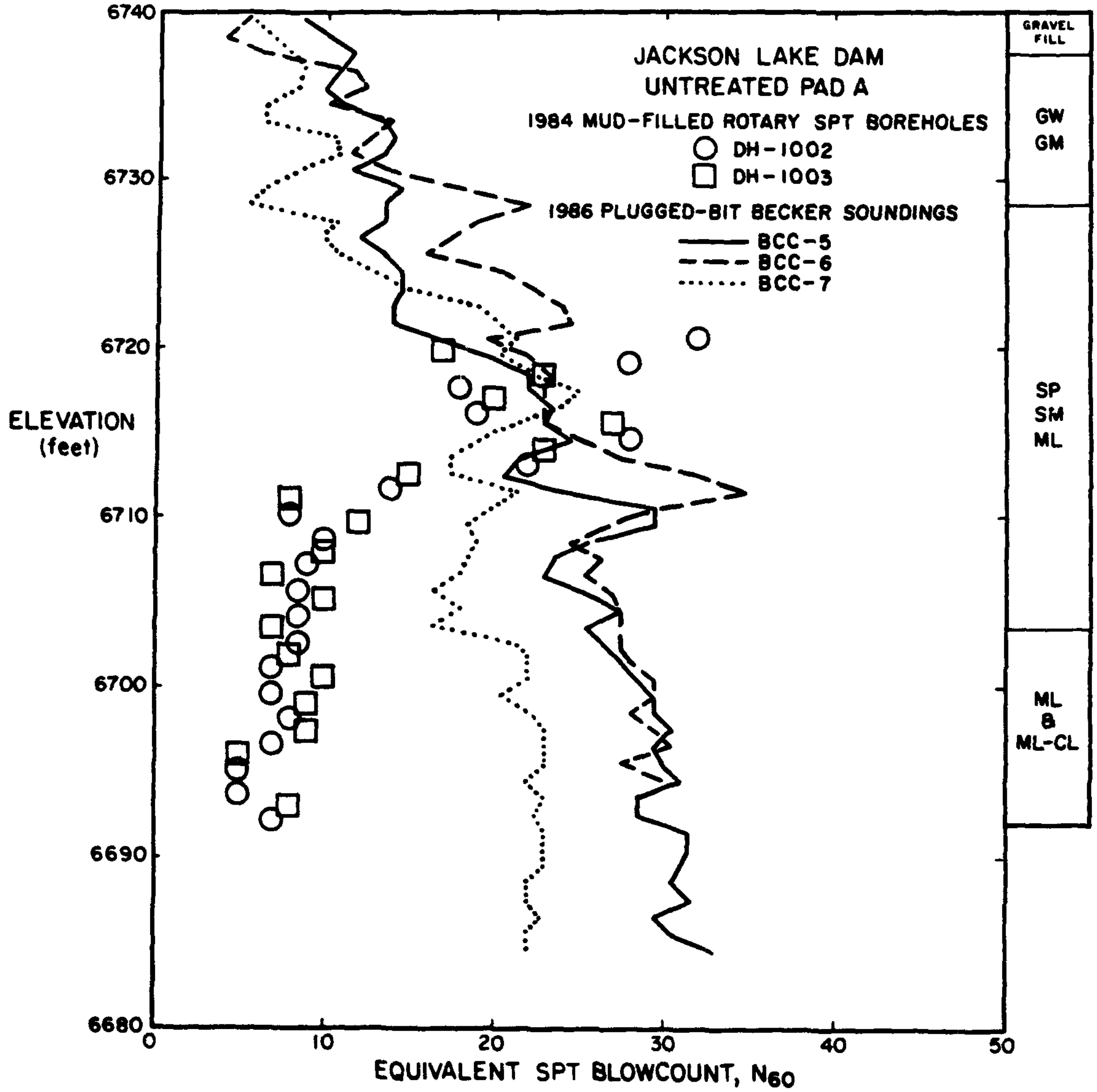


Figure 17: Comparison of Becker Equivalent SPT Blowcounts with SPT Blowcounts Obtained at Pad A Test Site at Jackson Lake Dam

There is no apparent explanation why the Becker penetrometer was unable to discover or "see" the low blowcount material in the lower elevation interval after generally matching the SPT results in the higher elevation interval. One idea might be that skin friction on the Becker casing resulted in so much resistance at larger depths that low blowcounts could not be measured regardless of the weakness of the material at the casing bit. However, if this was true, then the two different sets of penetration results in the upper elevation interval (i.e. between elevations 6713 and 6720 feet) should not match. The blowcount results at elevation 6713 match relatively well; but the results at elevation 6710 feet do not. It is not reasonable that the effects of casing friction should suddenly develop in only three feet. Furthermore, the effects of casing friction can be shown to be minimal in other Jackson Lake Dam soundings simply by showing low Becker blowcounts at significant depths. Figures 10 and 13 showed uncorrected Becker blowcounts of 9 or less at 30-foot depths in the soundings performed at Sectors H and A. In addition, plugged-bit soundings performed at Ririe Dam resulted in Becker blowcounts of 7 at a depth of 50 feet and blowcounts of 12 at 80 feet.

Unfortunately, there was no time to investigate why the Becker results were so far off in the lower elevations at this site. Possible explanations that would explain the discrepancies in the lower elevations at the Untreated Pad A site include:

1. The Becker soundings may have been performed in a different material than were the SPT tests. The alluvial foundation at Jackson Lake Dam is extremely variable.

2. The SPT tests were performed in 1984. Since that time and before the 1986 Becker soundings, the reservoir has been emptied to facilitate the treatment of the embankment and foundation. The removal of the reservoir loading and pore pressures could possibly significantly change the effective stresses in the foundation and thus affect the penetration resistance.

Overall Assessment of Jackson Lake Dam Results

The purpose of the Becker soundings performed at Jackson Lake Dam was to check and calibrate the correlation between corrected Becker and SPT blowcounts. Overall, the results indicated that the existing correlation between Becker and SPT blowcounts was good and needed no new adjustments. Although, the Becker results were not able to match the low SPT blowcounts in the lower intervals at one site, Pad A, the magnitude and nature of the disagreement indicated that this discrepancy was not a result of errors in the calibration of the energy corrections. Accordingly, the correlations and calibrations developed by Harder and Seed (1986) and outlined in Section 2 are judged appropriate for use at Ririe Dam.

4. BECKER EXPLORATIONS PERFORMED AT RIRIE DAM

Performance of 1986 Becker Soundings at Ririe Dam

The original plan for the explorations at Ririe Dam consisted of up to 15 soundings. However, after the field exploration program was started, the program was expanded to 18 plugged-bit and open-bit Becker soundings. These 18 soundings were performed with 6.6-inch O.D. casing at Ririe Dam between September 19, 1986 and September 27, 1986. Part of the original plan called for performing 3 soundings on the random zone upslope of the downstream berm. However, the Becker drill rig operator was unwilling to attempt drilling on the 5:1 slope without substantial modifications to the slope (i.e. creation of a road and work pads). Consequently, the three soundings tentatively planned to have been performed on this slope were performed on the upstream edge of the access road which crossed the downstream berm.

Thirteen soundings were performed through the embankment's downstream berm and 5 soundings were performed in the flat area beyond the downstream toe (see Figure 4). Table 3 summarizes some of the pertinent data concerning the eighteen soundings. In general, the 18 soundings were performed in pairs, one with a plugged bit and the other with an open bit, at nine locations. The plugged-bit soundings were to be performed in order to obtain penetration data and the open-bit soundings were to be performed with air recirculation to obtain samples of the material being penetrated. Table 4 presents a list of the 101 bag samples recovered showing the borings and depths from which they were obtained. The exceptions to this plan were as follows:

Table 3: 1986 Becker Penetration Soundings Performed at Ririe Dam

Sounding	Location	Approximate Ground Surface Elevation (ft)	Bit Configuration	Maximum Depth (ft)
BCC 86-1	Downstream Flat	4970	Plugged	71.
BCC 86-2	Downstream Flat	4972	Plugged	71.
BOC 86-2	Downstream Flat	4972	Open	68.
BCC 86-3	Downstream Flat	4971	Plugged	83.
BOC 86-3	Downstream Flat	4971	Open	85.
BCC 86-4	Downstream Berm	4998	Plugged	107.
BOC 86-4	Downstream Berm	4999	Open	108.
BCC 86-5	Downstream Berm	4995	Plugged	99.7
BOC 86-5	Downstream Berm	4995	Open	92.5
BCC 86-6	Downstream Berm	4995	Plugged	82.5
BOC 86-6	Downstream Berm	4995	Open	60.
BOC 86-6B	Downstream Berm	4995	Open	107.
BCC 86-7	Downstream Berm	4995	Plugged	97.
BOC 86-7	Downstream Berm	4994	Open	98.
BCC 86-8	Downstream Berm	4994	Plugged	90.
BOC 86-8	Downstream Berm	4994	Open	104.3
BCC 86-9	Downstream Berm	5003	Plugged	69.
BOC 86-9	Downstream Berm	5003	Open	68.

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Table 4: List of Recovered Samples from Open-Bit Becker Soundings Performed at Ririe Dam in September 1986

Sounding	BOC 86-2
B-1	8 - 17 ft
B-2	17 - 26 ft
B-3	26 - 34 ft
B-4	55 - 65 ft

Sounding	BOC 86-3
B-1	5 - 11 ft
B-2	11 - 15 ft
B-3	15 - 21 ft
B-4	21 - 27 ft
B-5	27 - 32 ft
B-6	32 - 38 ft
B-7a	42 - 48 ft
B-7b	48 - 55 ft
B-8	58 - 67 ft
B-9	68 - 71 ft
B-10	71 - 74 ft
B-11	75 - 78 ft

Sounding	BOC 86-4
B-1	22 - 28 ft
B-2	28 - 36 ft
B-3	36 - 43 ft
B-4	43 - 48 ft
B-5	50 - 56 ft
B-6	58 - 64 ft
B-7	71 - 78 ft
B-8	78 - 88 ft
B-9	88 - 96 ft
B-10	96 - 99 ft
B-11	99 -108 ft

Sounding	BOC 86-5
B-1	0 - 8 ft
B-2	8 - 16 ft
B-3	18 - 28 ft
B-4	28 - 38 ft
B-5	42 - 48 ft
B-6	48 - 58 ft
B-7	59 - 65 ft
B-8	65 - 68 ft
B-9	68 - 71 ft
B-10	71 ft
B-11	71 - 78 ft
B-12	82 - 88 ft
B-13	91 - 92.5 ft

Sounding	BOC 86-6
B-1	0 - 8 ft
B-2	8 - 14 ft
B-3	14 - 21 ft
B-4	21 - 28 ft
B-5	28 - 33 ft
B-6	33 - 39 ft
B-7	39 - 44 ft
B-8	44 - 48 ft
B-9	52 - 54 ft
B-10	54 - 58 ft

Sounding	BOC 86-6B
B-1	3 - 8 ft
B-2	8 - 18 ft
B-3	18 - 23 ft
B-4	23 - 29 ft
B-5	34 - 38 ft
B-6	38 - 43 ft
B-7	43 - 47 ft
B-8	47 - 54 ft
B-9	56 - 58 ft
B-10	58 - 64 ft
B-11	64 - 68 ft
B-12	68 - 74 ft
B-13	74 - 78 ft
B-14	84 - 88 ft
B-15	88 - 90 ft
B-16	90 - 98 ft
B-17	98 -104 ft
B-18	104-107 ft

Sounding	BOC 86-7
B-1	8 - 14 ft
B-2	14 - 19 ft
B-3	19 - 28 ft
B-4	28 - 36 ft
B-5	36 - 39 ft
B-6	39 - 48 ft
B-7	49 - 56 ft
B-8	58 - 68 ft
B-9	71 - 75 ft
B-10	75 - 78 ft
B-11	78 - 88 ft
B-12	95 - 98 ft

Sounding	BOC 86-8
B-1	16 - 18 ft
B-2	24 - 28 ft
B-3	32 - 38 ft
B-4	38 - 46 ft
B-5	46 - 52 ft
B-6	52 - 58 ft
B-7	58 - 64 ft
B-8	64 - 70 ft
B-9	70 - 71 ft
B-10	75 - 78 ft
B-11	78 - 84 ft
B-12	84 - 88 ft
B-13	88 - 98 ft
B-14	98 -104 ft

Sounding	BOC 86-9
B-1	8 - 16 ft
B-2	30 - 37 ft
B-3	40 - 44 ft
B-4	50 - 55 ft
B-5	55 - 58 ft
B-6	58 - 62 ft
B-7	66 - 68 ft

TOTAL NUMBER OF SAMPLES = 101

1. Plugged-bit sounding BCC 86-1 was located in the flat area downstream of the embankment. During the performance of this sounding, the casing was broken when the tip reached a depth of 71 feet. The casing was broken at a 21-foot depth just past a casing joint. This left approximately 50 feet of casing in the hole that the drillers were unable to recover. Shortly after the performance of this sounding, Sam Quilling, a local contractor who had been hired to clear access roads on the downstream berm came forward. Mr. Quilling had been present during the construction of Ririe Dam and stated that sounding BCC 86-1 was located in an area that had been overexcavated during construction for use as a borrow source. The depth of overexcavation was approximately 40 feet and had been backfilled with large boulders and soil. Because this site apparently did not have foundation soils representative of those beneath the dam and because of the high likelihood of additional casing losses, an open-bit sounding was not performed at this site.

2. Open-bit sounding BOC 86-6, located on the downstream berm approximately 150 feet from the left abutment, was performed approximately 20 feet to the left (looking downstream) of plugged-bit sounding BCC 86-6. However, this open-bit sounding encountered rock at a much shallower depth (approximately 55 feet) than did the plugged-bit sounding (at approximately 80 feet). The open-bit sounding apparently encountered a bench in the rock near the left abutment. This rock bench was also encountered in soundings BCC 86-9 and BOC 86-9. However, the depth to rock apparently changes very fast running to the right between open-bit sounding BOC 86-6 and plugged-bit sounding BCC 86-6. In order to obtain samples of the alluvium encountered at lower elevations by the plugged-bit sounding, an additional open-bit sounding, BOC 86-6B, was performed approximately 20 feet to the right of the plugged-bit sounding.

Cross-sections of Ririe Dam sent by Dave Sykora from Waterways Experiment Station indicated that the ground surface elevation of the flat area beyond the downstream toe of the dam is at approximately 4955 feet. Rough measurements made in the field during this investigation generally place this surface approximately 16 feet higher at about the 4971-foot elevation. It is believed that this difference is created by the presence of a pad of random fill that was placed downstream of the dam. There are many large boulders and cobbles in this random fill in both the downstream flat and within the downstream berm material. Nevertheless, except for some intervals of near refusal (i.e. very high blowcounts), the 6.6-inch O.D. Becker bit was able to be driven through this material and detect relatively low blowcount soils at lower elevations. This was rather amazing since the logs of a test shaft in the berm revealed the presence of boulders up to 5 feet in diameter (Reference 9).

Except for the loss of 50 feet of casing in sounding BCC 86-1, the performance of the 18 soundings was generally accomplished without major problems. There were, however, an above average amount of equipment breakdowns due to the fact that the casing was driven through materials which often had very high blowcounts. These materials included the bouldery and cobblely random fill, some dense gravels encountered in the foundation, and residual rock surfaces. The breakdowns would include broken bits, ruptured hoses, and fractured (fatigued) metal brackets. However, most breakdowns were repaired within an hour or so.

Appendix D presents borehole logs for the 18 Becker soundings performed at Ririe Dam. For the open-bit soundings, the remolded

samples obtained by air recirculation were field classified and their classifications are shown in later figures and in Appendix D.

Appendix E presents corrected bounce chamber pressure versus measured Becker blowcount data from the 18 Ririe Dam soundings. In general, this data shows that the diesel hammer efficiencies were generally similiar to slightly higher than the constant combustion rating curve (Curve AA in Figure 7) adopted for calibration.

The blowcount data from the 18 Becker soundings performed at Ririe Dam were converted into equivalent SPT N_{60} blowcounts using the procedures developed by Harder and Seed (1986) and outlined in Section 2. Appendix F presents calculation tables which were used for this process. Appendix G (attached seperately) contains slides of the drilling operation and recovered samples.

Correction to 1 tsf Overburden Pressure

Penetration test results are affected by both soil properties and by the effective pressures confining the soil. Thus, a loose soil at great depth and confinement can have a high blowcount and a dense soil tested at shallow depth and small confinement can have a low blowcount. To account for the effect of confinement, penetration tests are usually normalized to the blowcount that would result if the soil was tested at a depth corresponding to 1 tsf of overburden pressure. This normalization is accomplished by multiplying a measured blowcount, N, by a correction factor, C_N, to obtain the normalized blowcount, N_1 (Reference 6). Because the equivalent SPT blowcounts derived from Becker blowcounts using the correlation by Harder and Seed (1986) are in terms of N_{60} values (the SPT blowcount that would be obtained with a SPT hammer producing 60 percent of the free-fall energy of a 140-lb

hammer falling 30 inches), the formula for normalizing to 1 tsf overburden pressure is as follows:

$$(N_1)_{60} = C_N * N_{60}$$

where $(N_1)_{60}$ = Normalized and corrected SPT blowcount used with correlation by Seed et al. (1985) to predict cyclic strength.

N_{60} = Corrected or equivalent SPT blowcount derived from Becker Penetration Tests

C_N = Factor for correcting blowcounts to 1 tsf overburden pressure under level ground conditions

Studies have found that the C_N correction factor can vary as a function of both relative density and soil gradation. For overburden pressures greater than 1 tsf, the effect of the C_N correction is to reduce the blowcount. The studies by Marcuson and Bieganousky (1977a,b) indicate that as the soil becomes denser or becomes coarser and more well-graded, the magnitude of this reduction for higher overburden pressures decreases. To rigorously correct the Ririe Dam blowcount data to 1 tsf overburden pressure, the calculated stresses from finite element analyses together with correction curves for different types of soils would be necessary. Since finite element studies have not been performed, only preliminary corrections can be performed in this study. These preliminary corrections were performed using the following procedure:

1. Vertical effective stresses were calculated using the following assumed values:
   a. Vertical stresses were calculated using the simple γh approach.

b. Density test results from the shaft excavated in the berm suggest an average moist density for the random fill of 132 pcf and a saturated density for the predominantly gravelly alluvium of 144 pcf.

c. Water level measurements made on September 24, 1986 in piezometers P-24x and P-32x, located in the downstream berm, indicated a water surface elevation of about 4951 feet (Reference 10). This water surface elevation was assumed for both the berm and downstream flat areas.

2. Vertical effective stresses calculated by the γh approach were increased 15 percent to account for the added vertical and lateral pressures induced by the downstream slope. The 15 percent value was chosen because experience on previous projects indicated that the effect was of this general magnitude.

3. The C_N correction curve suggested by Seed et al. (1983) for loose to moderately dense sands was adopted as an overall average correction curve for the Ririe Dam and foundation soils.

Tables 5 and 6 present calculated C_N values for the berm and downstream flat soundings together with the N_{60} values at different depths which would correspond to $(N_1)_{60}$ values of 10, 20, and 30.

Presentation of Results

Shown in Figures 18 through 26 are the uncorrected blowcounts obtained from the 1986 Becker Soundings performed at Ririe Dam. Also shown are the equivalent SPT N_{60} blowcounts together with dashed lines representing different levels of blowcount normalized to 1 tsf overburden pressure. Figures 18 through 20 present results obtained in the downstream flat area. Figures 21 through 26 show results from the soundings conducted through the downstream berm of the embankment. As already discussed in Section 3, an open-bit sounding was performed in

Table 5: Preliminary Overburden Correction Values for Soundings Performed in the Downstream Flat at Ririe Dam

Depth (ft)	σ_y' (psf)	$(1.15 \times \sigma_y')$ (psf)	C_N	N_{60} $(N_1)_{60}$ = 10	20	30
10	1320	1520	1.15	8.7	17.4	26.1
20	2640	3040	0.81	12.3	24.7	37.0
30	3460	3970	0.68	14.7	29.4	44.1
40	4270	4910	0.60	16.7	33.3	50.0
50	5090	5850	0.54	18.5	37.0	55.6
60	5900	6790	0.49	20.4	40.8	61.2
70	6720	7730	0.46	21.7	43.5	65.2

Table 6: Preliminary Overburden Correction Values for Soundings Performed in the Downstream Berm at Ririe Dam

Depth (ft)	σ_y' (psf)	$(1.15 \times \sigma_y')$ (psf)	C_N	N_{60} $(N_1)_{60}$ = 10	20	30
10	1320	1520	1.15	8.7	17.4	26.1
20	2640	3040	0.81	12.3	24.7	37.0
30	3960	4550	0.64	15.6	31.3	46.9
40	5280	6070	0.52	19.2	38.5	57.7
50	6300	7240	0.48	20.8	41.7	62.5
60	7110	8180	0.45	22.2	44.4	66.7
70	7930	9120	0.43	23.3	46.5	69.8
80	8750	10060	0.40	25.0	50.0	75.0
90	9560	11000	0.37	27.0	54.1	81.1
100	10380	11930	0.35	28.6	57.1	85.7

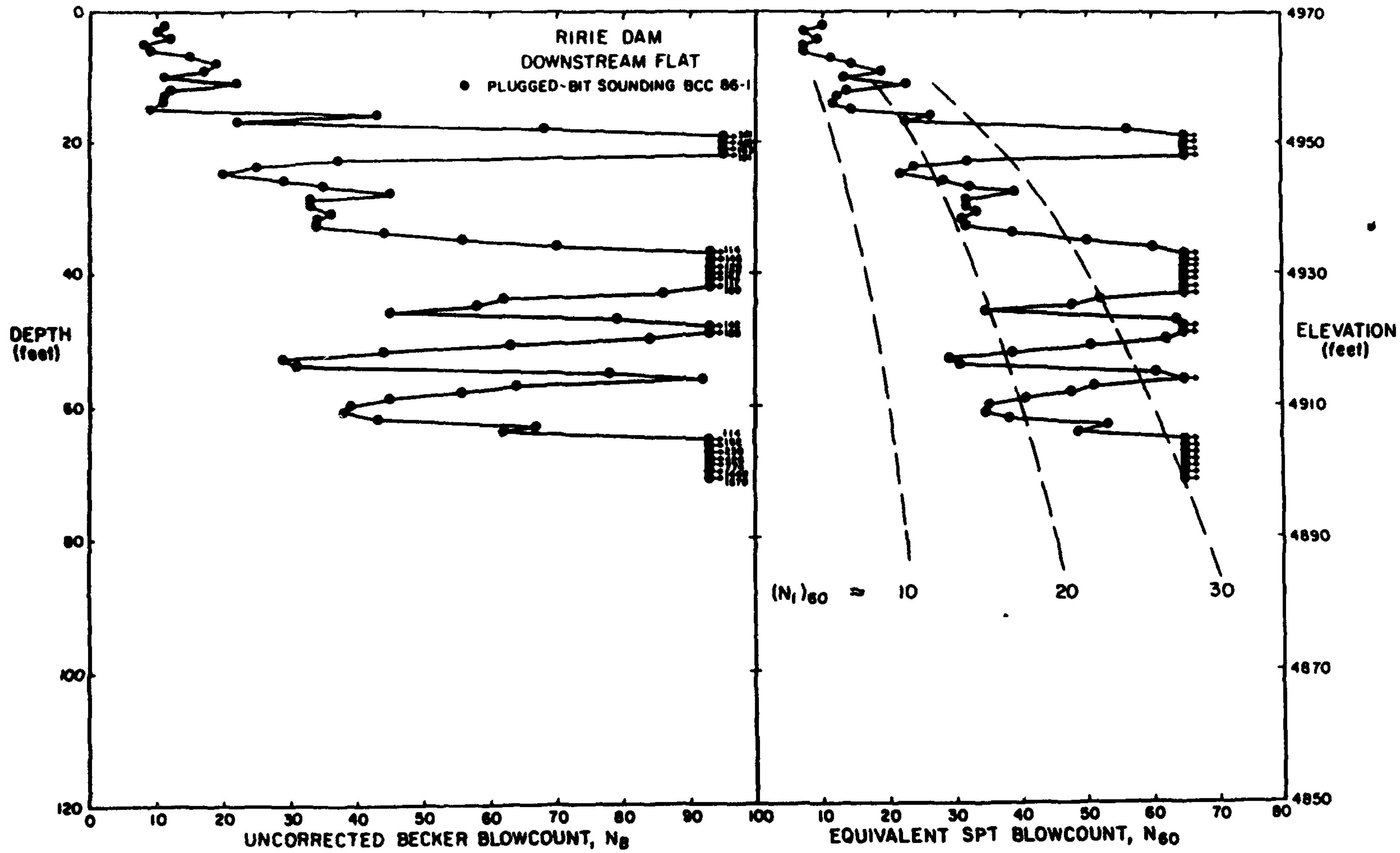


Figure 18: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 1

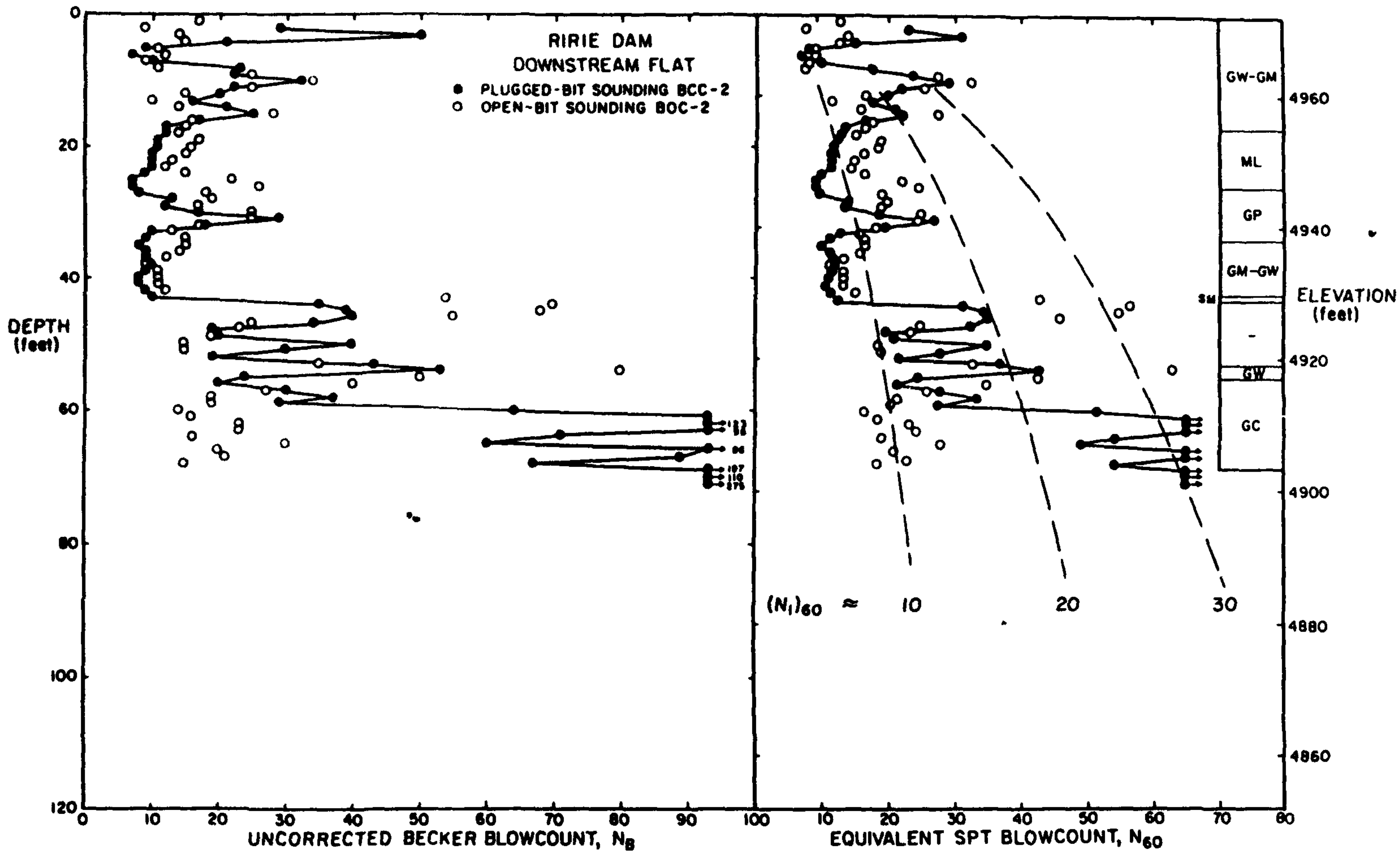


Figure 19: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 2

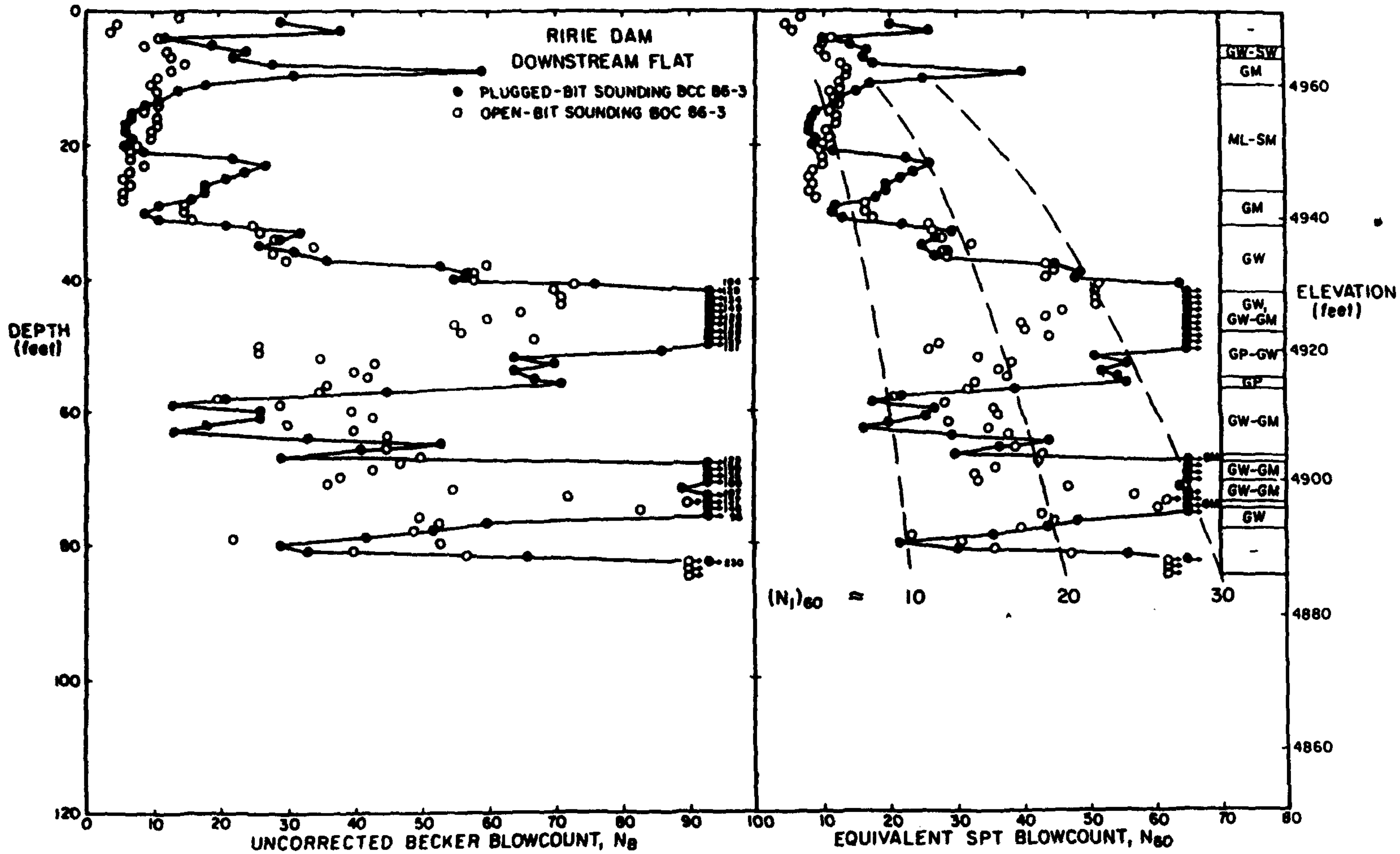


Figure 20: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 3

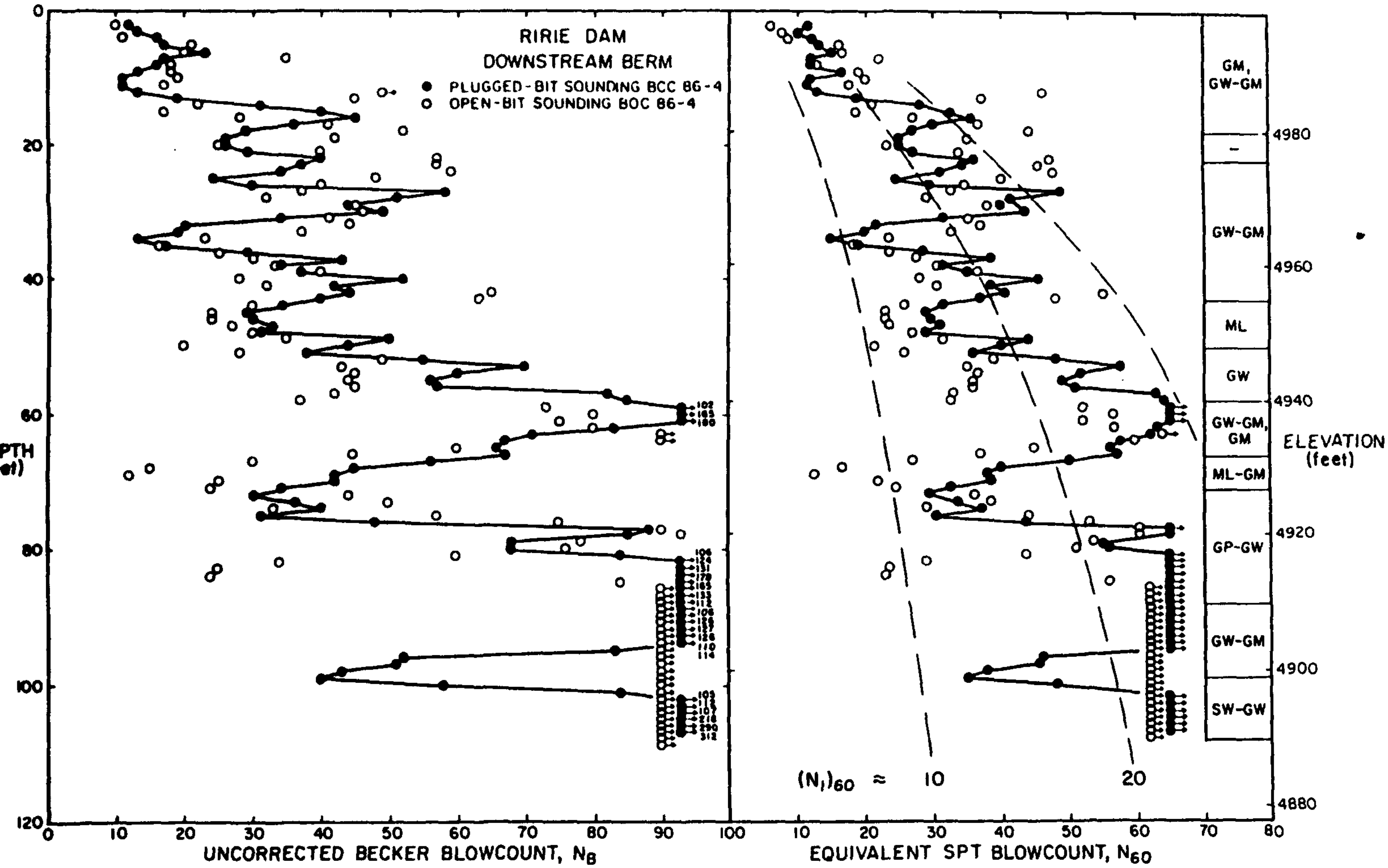


Figure 21: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 4

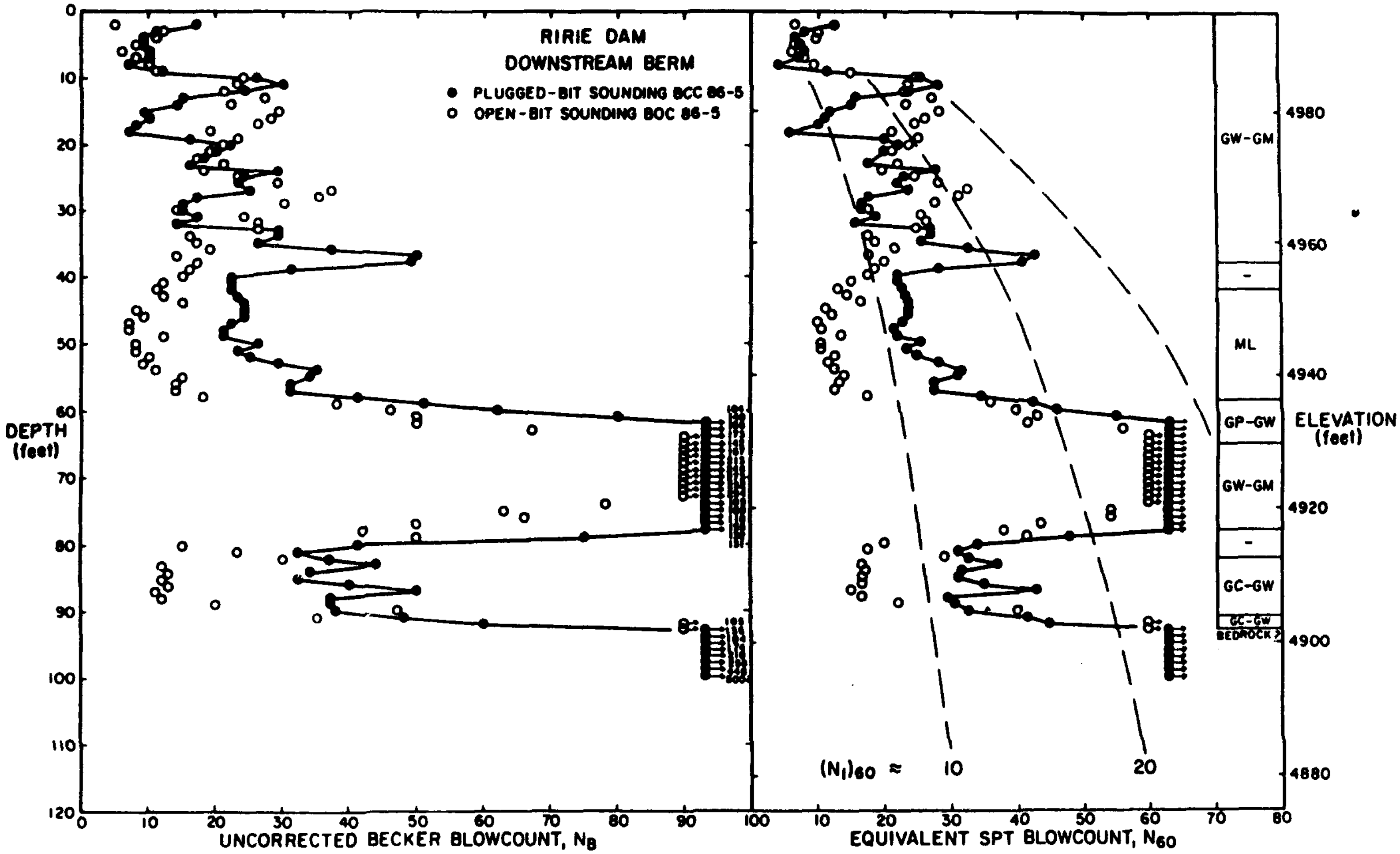


Figure 22: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 5

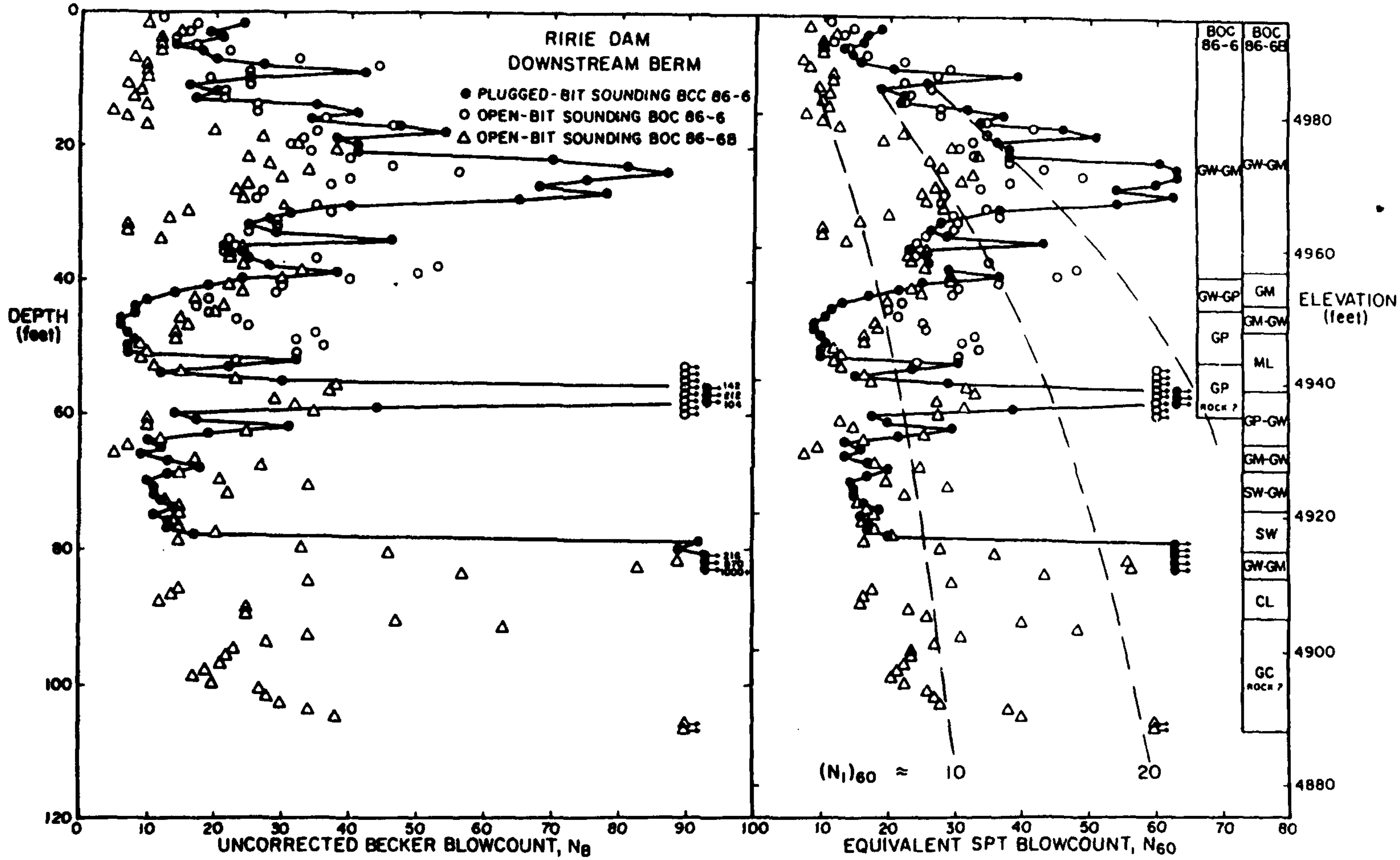


Figure 23: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 6

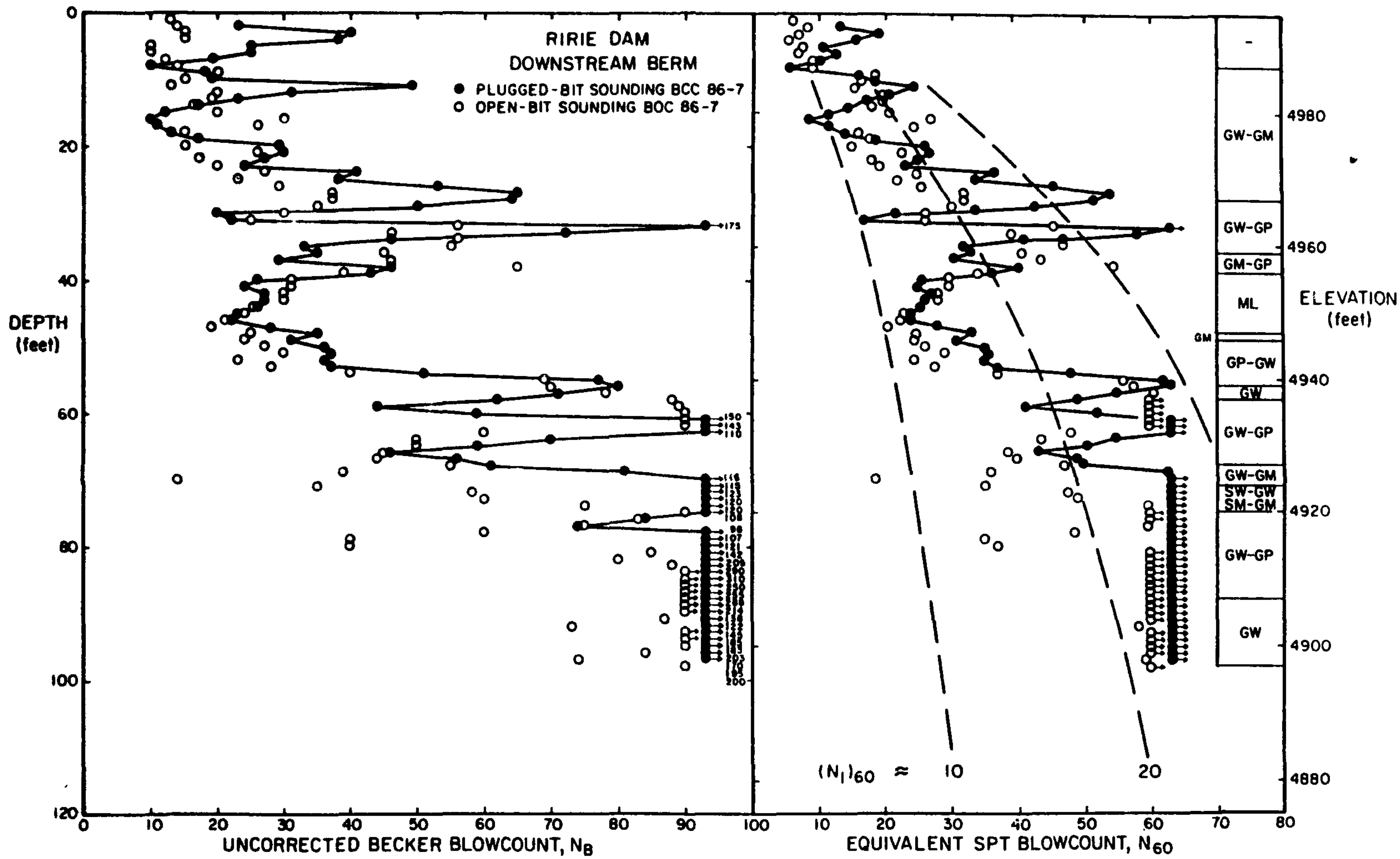


Figure 24: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 7

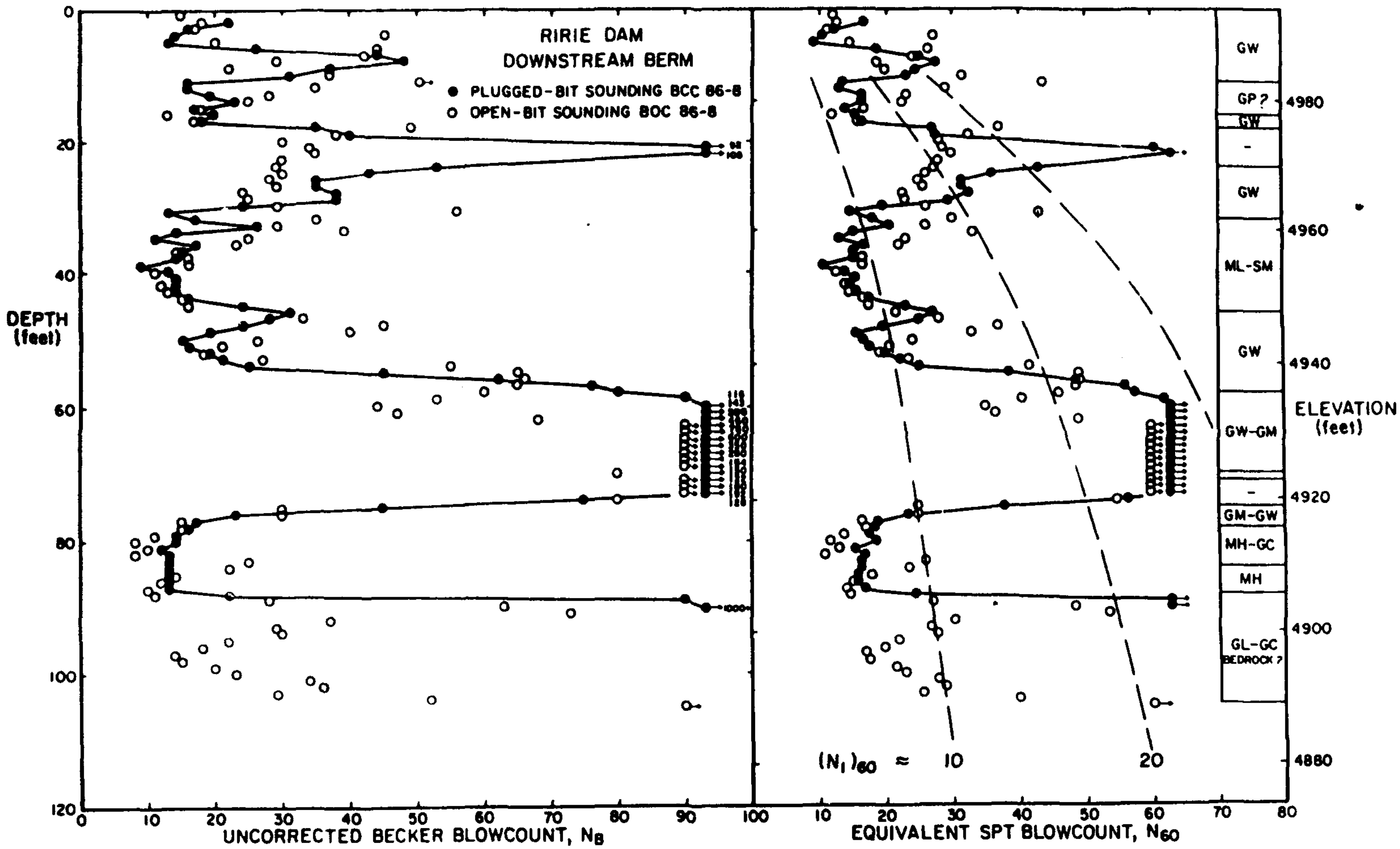


Figure 25: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 8

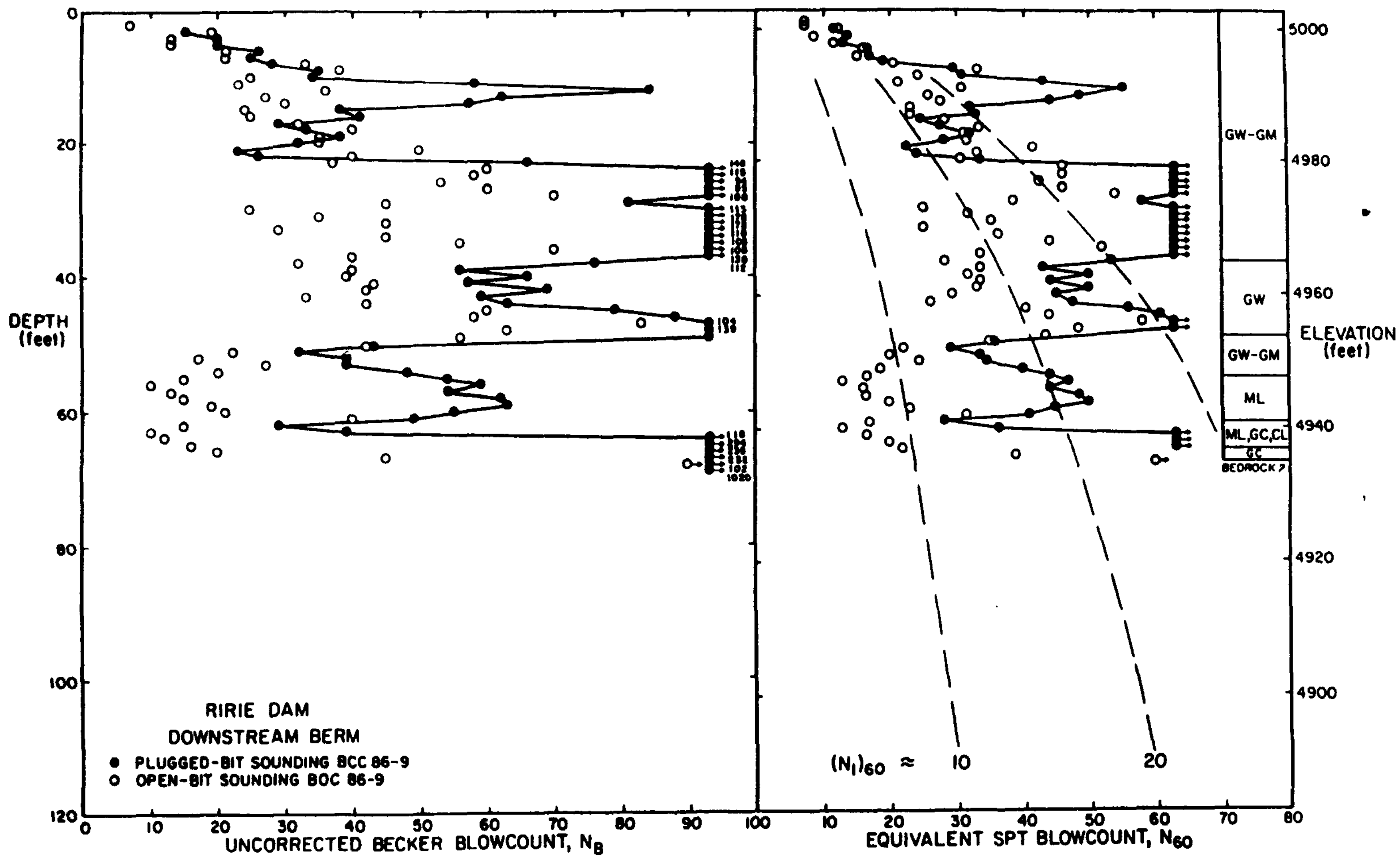


Figure 26: Uncorrected Becker and Equivalent SPT Blowcounts for Soundings Performed at Ririe Dam - Site 9

close proximity to a plugged-bit sounding at most locations. At these locations, the spacings between the two types of soundings was generally about 20 feet.

One significant point that requires noting is that the correlation developed by Harder and Seed (1986) between Becker and SPT blowcounts is for use with plugged Becker bits having outside diameters of 6.6-inches. Use of the open bit with air recirculation sometimes draws up excessive amounts of soil and water ahead of the bit and into the casing. When this happens, the loosening and removal of material ahead of the bit leads to a relatively low blowcount. Although this effect appears to be most significant in saturated sands, it is sometimes important in gravelly soils as well. For the tests performed at Ririe Dam, the results generally show that the open-bit BOC soundings gave comparable but somewhat lower equivalent SPT blowcounts than did the plugged-bit BCC soundings (Figures 19 through 26). In some cases, the open-bit BOC soundings actually gave much lower blowcounts than did the plugged-bit soundings performed in the same material at the same depth. Because of the heave problem apparently present in limited degree for the Ririe Dam open-bit soundings, the equivalent blowcounts from plugged-bit soundings are considered more reliable indicators of cyclic strength.

The results of the 1986 Becker soundings performed in Ririe Dam reveal the following conditions in the embankment and foundation alluvium:

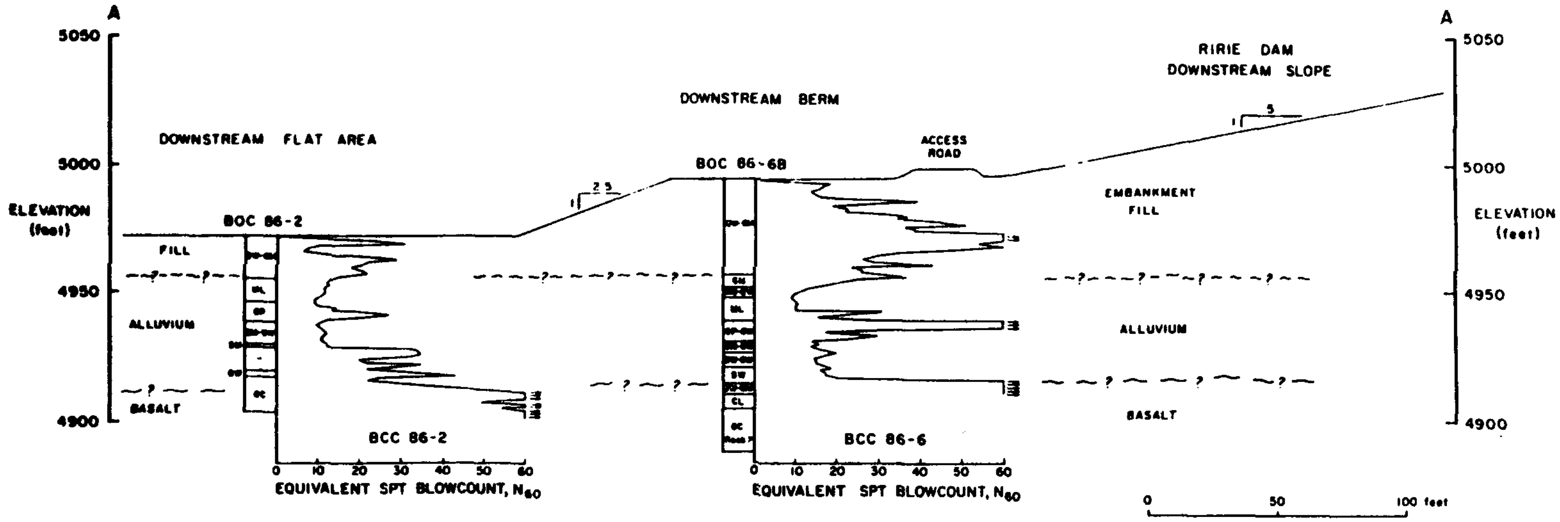
1. The downstream berm of Ririe Dam is composed of random zone material and is approximately 35 to 40 feet thick. According to the samples recovered from the open-bit soundings performed in this berm, the random zone is composed of a

silty, sandy gravel with cobbles. This agrees with the log of the test shaft excavated in this material (Reference 9) which also shows the presence of large boulders. Although the presence of boulders and cobbles may create unrepresentatively high blowcounts in some intervals, this effect can be accounted for by discounting thin intervals of very high blowcount and adopting a low average for characterizing this material. Accordingly, the Becker data suggests a representative equivalent SPT $(N_1)_{60}$ value of about 20 blows per foot.

2. Figures 21 through 26 show that there is a layer of low blowcount sandy silt in the upper portion of the alluvium below the berm. This silt layer was found in every open-bit sounding, including two performed in the downstream flat, and is approximately 7 to 16 feet thick. Figures 27 and 28 present transverse and longitudinal sections across the berm which illustrate the continuity of this layer. The Becker data determine equivalent SPT $(N_1)_{60}$ blowcounts which generally range between 5 and 20 blows per foot in this material (see Figures 19 through 26).

3. Most of the Becker soundings show the presence of a relatively low blowcount layer of sandy gravel and/or gravelly sand lying beneath the sandy silt layer. The thickness of this layer ranges approximately between 0 to 17 feet. The Becker data indicate equivalent SPT $(N_1)_{60}$ blowcounts which generally range between 5 and 25 blows per foot in this material (see Figures 19 through 26).

4. Below about Elevation 4935 feet, the Becker soundings generally indicate high blowcount gravel or rock. Although some soundings show isolated zones of low blowcount lenses of gravel, these zones appear to be discrete and discontinuous. For two soundings, BCC-5 and BCC-8, there appears to be a low blowcount clayey zone, perhaps weathered rock, lying above bedrock.



NOTE: FOUNDATION BORING PRESENTED ABOVE IS ONLY APPROXIMATELY LOCATED

Figure 27: Transverse Section View of Downstream Berm at Ririe Dam Showing Data From 1986 Becker Soundings

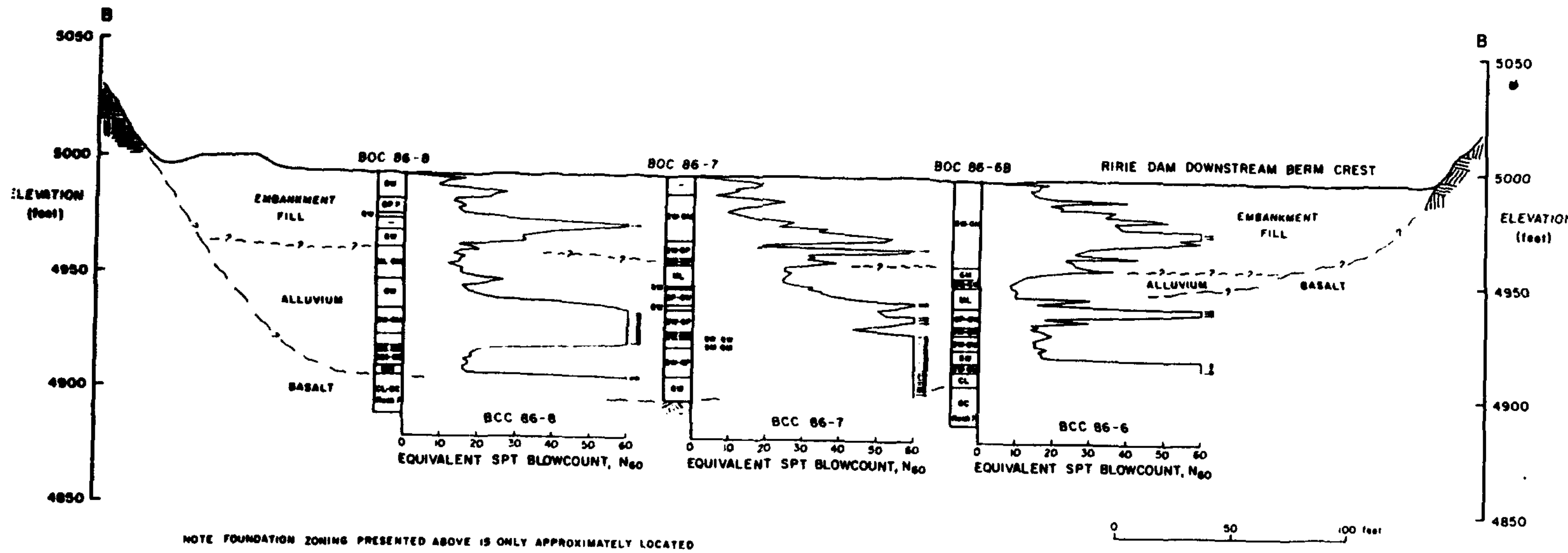


Figure 28: Longitudinal Section View of Downstream Berm at Ririe Dam Showing Data From 1986 Becker Soundings

5. The elevation at which basalt bedrock was believed to have been encountered generally ranges between 4880 and 4900 feet. There is some amount of uncertainty concerning at what point rock is actually encountered because the samples recovered during the performance of the open-bit soundings indicated the presence of weathered rock surfaces lying above more sound rock. Soundings BCC-9, BOC-9, and BOC-6, located near the left abutment, apparently encountered rock at approximately elevation 4940 feet. This indicated the presence of a rock bench on the left side of the channel.

5. DETERMINATION OF CYCLIC STRENGTH

Suggested Characterization of Random Zone and Alluvium

Figure 29 presents a summary plot of equivalent SPT N_{60} blowcounts and soil types encountered by the 6 Becker soundings performed through the downstream berm. The scatter in blowcount data illustrates the variability in both vertical and horizontal dimensions. Despite the significant amount of scatter in the blowcount data, the zoning and blowcount data suggests that the embankment and foundation materials can be characterized into 4 major zones:

Zone	Elevation Interval (ft)	Soil Type	Approx. Mean Equivalent SPT $(N_1)_{60}$
1 (Random Fill)	4955-4995	Silty, sandy gravel with cobbles/boulders	20
2 (Alluvium)	4945-4955	Sandy Silt	12
3 (Alluvium)	4940-4945	Sandy gravel/gravelly sand	16
4 (Alluvium)	4900-4940	Silty, sandy gravel	30
(Basalt)	-4900		

Figure 30 present curves showing where the approximate mean $(N_1)_{60}$ blowcounts listed above fall within the blowcount scatter. The above characterization is suggested as a one-dimensional model that would be representative of the soil conditions through the berm within the central portion of the channel (i.e. not near either abutment).

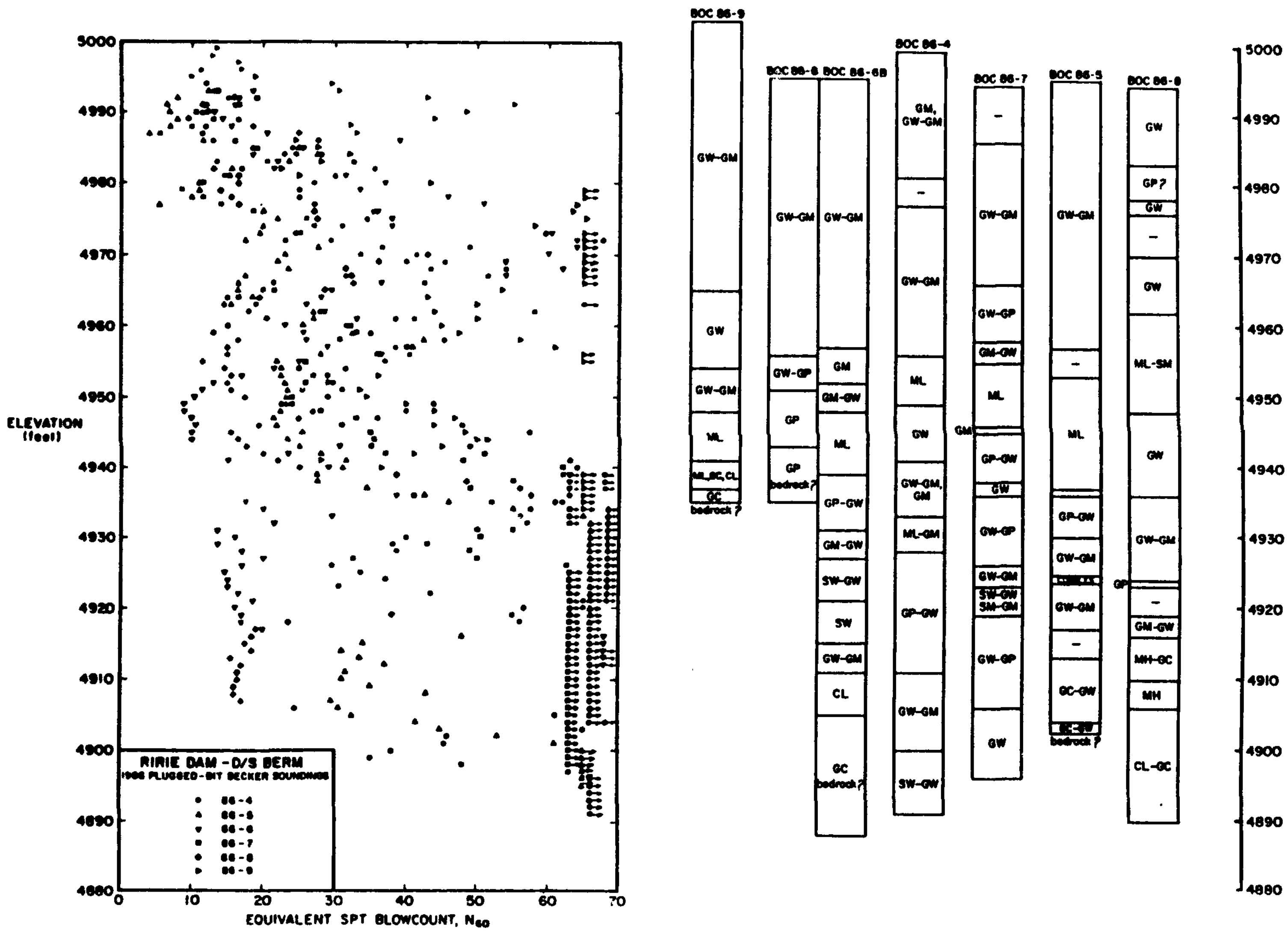


Figure 29: Summary Plot of Equivalent SPT Blowcounts Obtained from 1986 Becker Soundings Performed Through Downstream Berm at Ririe Dam

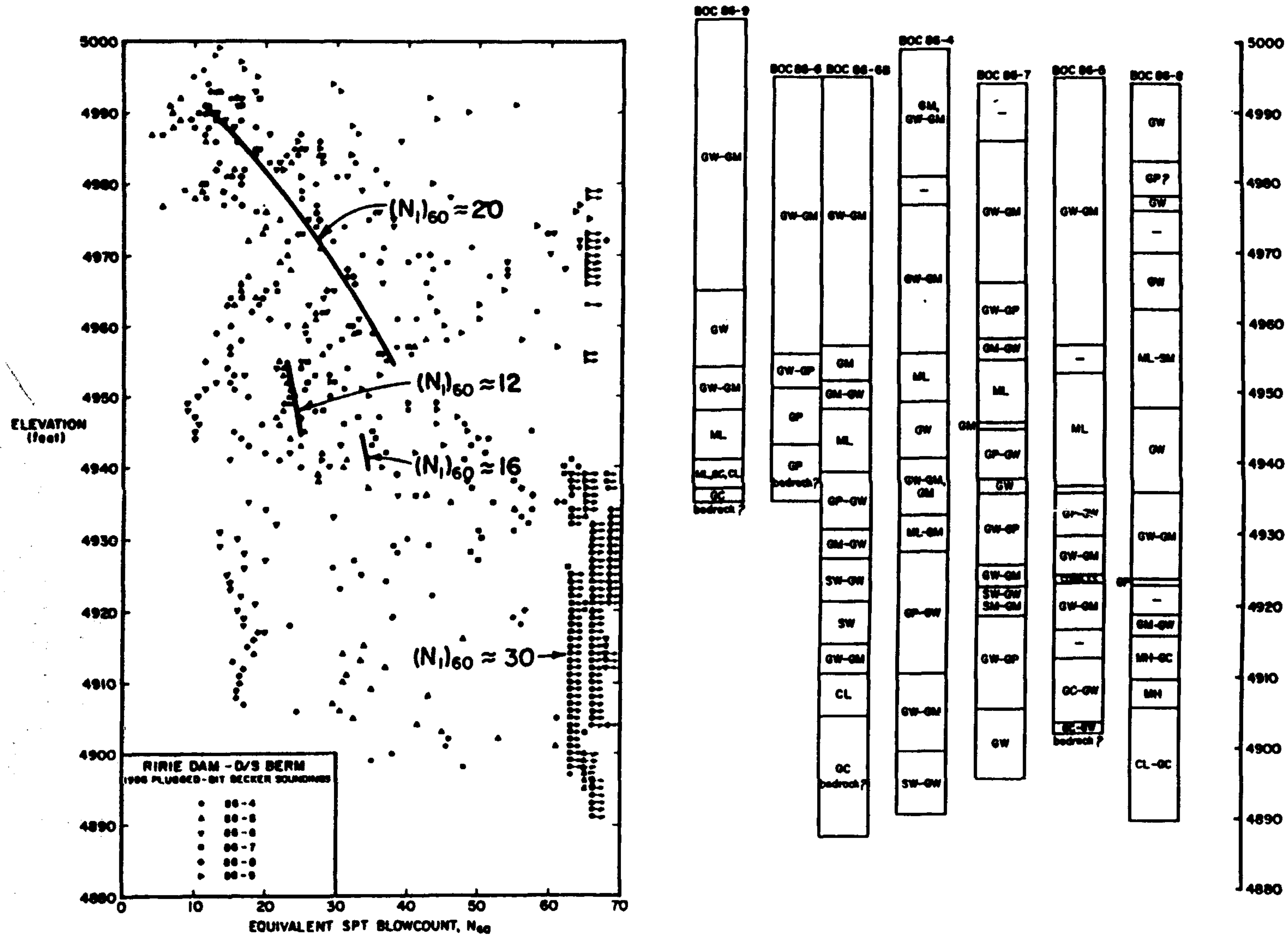


Figure 30: Suggested Representative Equivalent SPT Blowcounts for Soils Within and Beneath Downstream Berm at Ririe Dam

Determination of Cyclic Strength

The determination of cyclic strength in this investigation is made by using the Becker-derived equivalent SPT $(N_1)_{60}$ values together with the correlation by Seed et al. (1985) between SPT blowcount and cyclic strength. This correlation is presented in Figure 31 and gives the cyclic strength in terms of an average cyclic stress ratio, (τ_a / σ_o'). This cyclic stress ratio is a normalized cyclic strength that is consistent with about 15 equivalent uniform cycles of shaking (assuming an average amplitude equal to 65 percent of the peak motion). Fifteen equivalent uniform cycles is the number that would be produced by a magnitude 7.5 earthquake. In this figure, three different curves are available for determining cyclic strength. The proper curve is selected by determining how high a fines content (i.e. percent finer than the No. 200 sieve size) is present in the soil. For the same blowcount, an increase in fines content also increases the cyclic strength. Unfortunately, fines contents from classification tests for the Becker samples are not available and, consequently, must be estimated in this report. Table 7 presents the equivalent SPT $(N_1)_{60}$ values, assumed fines contents, and cyclic stress ratios (for saturated conditions) determined for the 4 major zones of material encountered at Ririe Dam.

It should be noted that the cyclic stress ratio represents the normalized strength for the following stress conditions:

1. Level ground conditions with a lateral earth pressure at rest coefficient, K_o, equal to about 0.4.
2. Overburden pressures between 0.5 and 1.5 tsf.

For stress conditions other than those above, corrections are available to modify the cyclic stress ratio. These corrections should be used together with results from finite element static stress analyses.

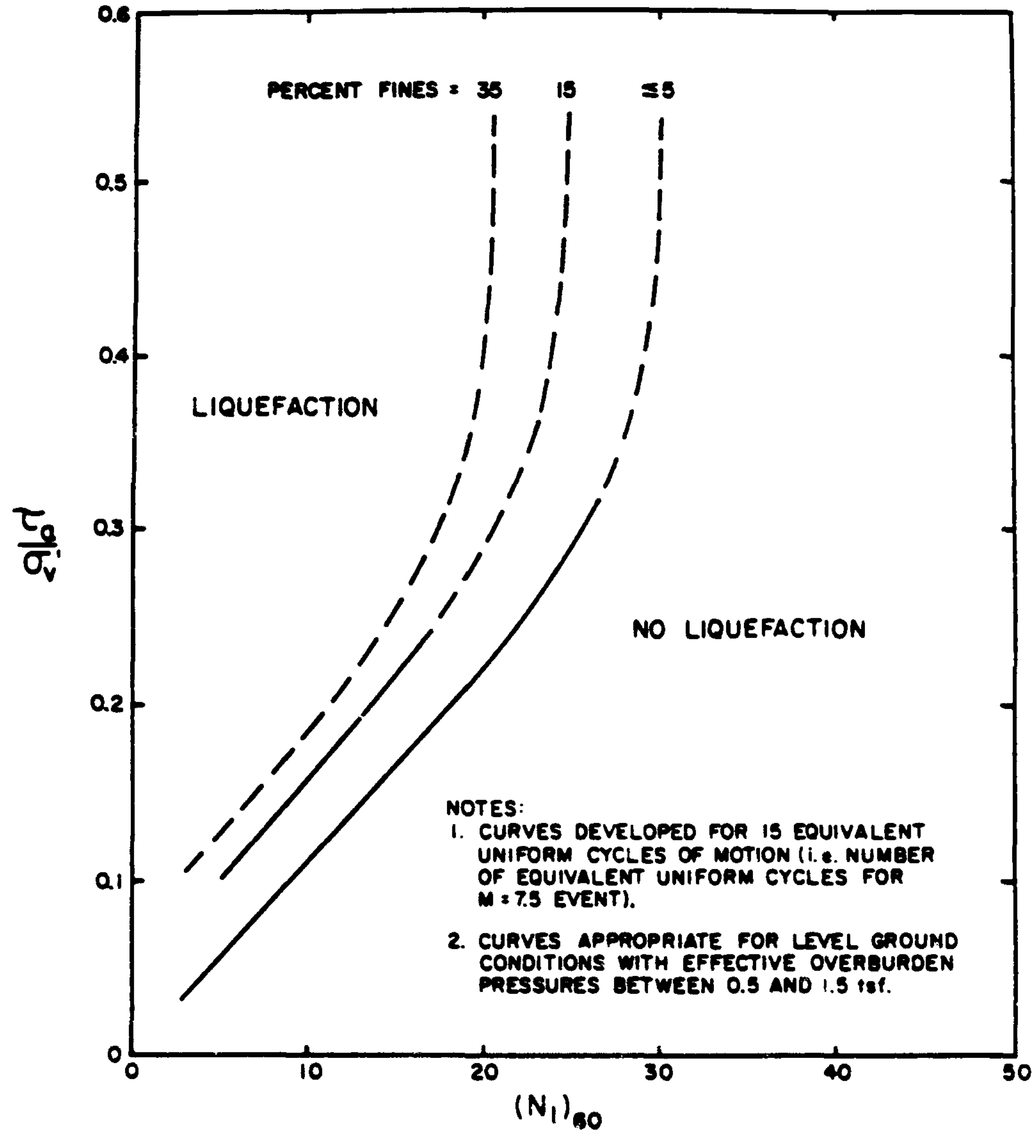


Figure 31: Relationship Between Corrected SPT Blowcount and Average Cyclic Stress Ratio Causing Liquefaction for M = 7.5 Earthquakes (after Seed et al., 1985)

Table 7: Summary of Cyclic Strengths Determined for Ririe Dam Soils

Zone	Material	Elevation Interval (ft)	Vertical Thickness (ft)	Soil Type	Approximate Mean $(N_1)_{60}$	Assumed Fines Content (%)	Cyclic Stress Ratio M=7.5
1	Random Fill	4955 - 4995	40	Silty, sandy, gravel with cobbles	20	10	0.26
2	Alluvium	4945 - 4955	10	Sandy silt	12	60	0.21
3	Alluvium	4940 - 4945	5	Sandy gravel/ gravelly sand	16	7	0.20
4	Alluvium	4900 - 4940	40	Silty, sandy, gravel	30	10	> 0.5

6. SUMMARY OF FINDINGS

1. Although there was a lack of correspondence between Becker blowcounts and SPT blowcounts for some zones at one of the test sites at Jackson Lake Dam, most of the data indicated relatively good agreement between equivalent SPT blowcounts derived from Becker soundings and actual SPT data obtained by the U.S. Bureau of Reclamation.

2. The Becker soundings performed at Ririe Dam indicated that the random fill zone comprising the downstream berm consists of a moderately dense silty, sandy gravel with cobbles.

3. In general, the alluvium beneath the downstream berm is approximately 55 feet thick:

   a. On the average, approximately the top 15 feet of alluvium consists of relatively loose soil. On average, the upper 10-foot interval consists of a low blowcount sandy silt with the generally lower 5-foot interval composed of a low blowcount sandy gravel.

   c. The bottom 40 feet of the alluvium generally consists of a dense sandy gravel. However, there are discontinuous lenses of relatively loose sandy gravel and clay embedded within this zone.

4. Table 7 summarized the major zones, equivalent SPT blowcounts, assumed fines contents, and determined cyclic stress ratios.

7. REFERENCES

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Appendix A: Borehole Logs for 1986 Becker Soundings Performed at Jackson Lake Dam

BECKER DRILL LOG

Hole No. BCC-1
Surf. Elev. 6755.6 ft.
Max. Depth 58. ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/15/86
Feature Jackson Lake Dam SPT-BECKER Correlation — Attitude Vertical
Location Sector H - N1164930.56, E365661.05 — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					28	13.5	
	5				26	13.5	
					24	13.	
					17	10.5	
					16	9.5	
					13	10.5	
	10				12	9.5	
					8	9.5	
					4	7.5	
					7	9.5	
					14	11.	
	15				16	11.	
					15	11.	
					10	9.	
					5	8.	
					5	8.5	
	20				8	9.	
					7	9.	
					5	9.	
					6	9.	
					4	9.	
	25				5	9.	
					8	9.	
					8	9.	
					7	10.5	
					14	11.	
	30				11	11.5	
					10	12.5	
					15	11.5	
					13	14.	
					21	14.5	
	35				23	13.5	
					22	14.	
					23	16.	
					30	16.	
					30	16.	
	40				38	16.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-1 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					41	16.	
					43	17.	
					50	17.	
					51	16.5	
	45				42	16.5	
					36	15.5	
					34	17.	
					38	16.	
					32	16.5	
	50				34	16.	
					32	15.5	
					28	15.5	
					32	15.5	
					32	15.5	
	55				32	16.	
					32	16.	
					36	16.5	
	58				29	16.	

BECKER DRILL LOG

Hole No. BCC-2
Surf. Elev. 6755.3 ft.
Max. Depth 58. ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/15/86
Feature Jackson Lake Dam SPT-BECKER Correlation — Attitude Vertical
Location Sector H - N1164931.48, E365680.07 — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					12	12.	
					19	14.	
					25	16.	
	5				26	15.5	
					25	15.	
					22	14.5	
					19	13.	
					17	12.5	
	10				14	12.5	
					14	12.5	
					18	14.	
					20	13.	
					18	10.5	
	15				10	7.	
					6	6.	
					3	5.	
					4	4.	
					4	9.	
	20				4	8.	
					4	10.	
					5	11.	
					7	9.	
					4	8.	
	25				4	10.	
					7	11.	
					6	11.5	
					6	12.	
					13	12.5	
	30				11	12.5	
					12	13.	
					17	13.5	
					23	15.	
					27	14.5	
	35				27	14.	
					28	14.	
					26	14.	
					25	14.	
					26	14.	
	40				29	15.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-2 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					31	15.5	
					28	15.	
					30	15.	
					34	14.5	
	45				28	14.	
					22	13.	
					20	13.	
					22	13.	
					26	14.5	
	50				33	14.5	
					30	14.5	
					25	13.5	
					24	13.5	
					32	14.	
	55				36	14.	
					38	15.	
					35	15.	
	58				44	16.	

B E C K E R   D R I L L   L O G

Hole No. BCC-3
Surf. Elev. 6756.2 ft.
Max. Depth 58. ft.

Project: RIRIE DAM SEISMIC STABILITY — Date Drilled: 9/15/86
Feature: Jackson Lake Dam SPT-BECKER Correlation — Attitude: Vertical
Location: Sector H - N1164959.62, E365669.88 — Logged by: L. F. Harder
Driller: Ken Arnold — Drill Rig: AP-1000 (No. 57) — Depth to water: ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					13	12.	
					18	14.5	
					22	14.	
	5				27	15.	
					29	16.	
					20	14.	
					13	12.	
					10	10.5	
	10				5	10.	
					4	11.5	
					7	12.	
					13	13.	
					8	10.	
	15				4	10.	
					3	9.	
					2	8.	
					3	7.	
					2	10.	
	20				3	10.	
					4	10.	
					10	10.	
					5	10.	
					3	10.	
	25				4	10.	
					5	10.	
					8	10.	
					6	10.5	
					7	11.	
	30				8	15.	
					15	15.	
					22	15.	
					21	15.5	
					21	15.	
	35				21	14.5	
					24	14.5	
					21	14.5	
					23	13.5	
					26	16.	
	40				28	16.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-3 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					29	15.5	
					29	16.	
					27	15.5	
					22	15.	
	45				27	16.	
					40	17.	
					41	17.	
					33	16.	
					29	16.	
	50				24	15.5	
					25	16.	
					33	16.	
					46	16.5	
					47	18.	
	55				40	17.5	
					39	17.	
					37	17.	
	58				42	16.	

B E C K E R   D R I L L   L O G

Hole No. BCC-4
Surf. Elev. 6771.0 ft.
Max. Depth 58. ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/15/86
Feature Jackson Lake Dam SPT-BECKER Correlation — Attitude Vertical
Location Sector A - N1167046.1, E365560.4 — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ____ ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					16	12.5	
					16	10.5	
					17	14.	
	5				18	14.	
					16	13.	
					16	13.	
					15	13.	
					10	10.5	
	10				10	11.	
					24	15.5	
					24	15.	
					31	16.5	
					40	17.5	
	15				45	18.	
					50	18.	
					53	17.5	
					51	17.	
					47	17.	
	20				46	17.	
					41	16.	
					36	15.5	
					35	15.5	
					36	15.5	
	25				37	16.	
					38	16.5	
					34	14.5	
					20	13.5	
					12	12.5	
	30				9	12.	
					12	16.	
					39	17.	
					50	17.	
					49	16.5	
	35				44	16.	
					37	16.	
					40	16.5	
					50	17.	
					38	16.5	
	40				38	16.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-4 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					28	15.5	
					27	14.5	
					29	15.	
					28	15.	
	45				29	15.	
					26	14.5	
					21	14.	
					19	14.5	
					20	15.	
	50				18	15.	
					23	15.5	
					27	16.5	
					28	16.5	
					30	16.5	
	55				34	16.	
					32	15.5	
					29	15.5	
	58				30	16.	

B E C K E R   D R I L L   L O G

Hole No. BCC-5
Surf. Elev. 6742.4 ft.
Max. Depth 58. ft.

Project: RIRIE DAM SEISMIC STABILITY — Date Drilled: 9/15/86
Feature: Jackson Lake Dam SPT-BECKER Correlation — Attitude: Vertical
Location: Untreated Pad A - N1163666.3, E366618.9 — Logged by: L. F. Harder
Driller: Ken Arnold — Drill Rig: AP-1000 (No. 57) — Depth to water: ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					9	10.	
					12	11.5	
					14	12.	
	5				15	13.	
					13	13.5	
					13	12.	
					14	13.	
					12	13.	
	10				13	13.	
					11	14.	
					11	12.	
					14	13.	
					12	13.	
	15				13	12.5	
					11	12.5	
					13	12.5	
					14	13.	
					14	13.	
	20				13	13.	
					13	13.	
					15	14.	
					19	15.	
					23	15.	
	25				23	15.5	
					24	16.	
					23	16.	
					26	16.	
					21	15.5	
	30				20	15.5	
					24	16.5	
					32	17.5	
					33	17.	
					27	16.5	
	35				24	16.	
					23	16.	
					27	16.5	
					30	17.	
					27	16.5	
	40				28	17.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-5 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					30	17.	
					31	17.5	
					32	17.5	
					32	18.	
	45				33	18.	
					32	18.	
					33	17.5	
					36	17.	
					32	17.	
	50				30	18.	
					35	18.	
					35	18.	
					33	18.5	
					34	17.5	
	55				34	18.5	
					32	18.	
					32	18.5	
	58				37	18.	

B E C K E R   D R I L L   L O G

Hole No. BCC-6
Surf. Elev. 6742.6 ft.
Max. Depth 48. ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/15/86
Feature	Jackson Lake Dam SPT-BECKER Correlation	Attitude	Vertical
Location	Untreated Pad A - N1163646.3, E366653.0	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					7	9.5	
					6	10.	
					4	9.	
	5				11	9.	
					15	13.	
					17	13.	
					14	12.	
					13	13.	
	10				11	13.	
					11	12.	
					12	13.	
					17	14.5	
					23	15.5	
	15				20	14.	
					19	13.	
					16	13.	
					22	14.5	
					-	15.	
	20				25	16.	
					27	15.5	
					19	15.	
					23	15.	
					25	15.5	
	25				24	15.5	
					24	15.5	
					24	15.5	
					28	16.	
					30	17.	
	30				35	18.5	
					41	18.	
					33	17.	
					30	16.	
					26	16.	
	35				29	16.5	
					27	16.5	
					30	16.5	
					32	16.	
					29	17.5	
	40				29	17.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-6 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					31	17.	
					33	17.	
					32	17.5	
					32	16.5	
	45				32	17.5	
					34	17.5	
					31	16.5	
	48				33	17.5	

B E C K E R   D R I L L   L O G

Hole No. BCC-7
Surf. Elev. 6742.4 ft.
Max. Depth 58. ft.

Project: RIRIE DAM SEISMIC STABILITY — Date Drilled: 9/15/86
Feature: Jackson Lake Dam SPT-BECKER Correlation — Attitude: Vertical
Location: Untreated Pad A - N1163705.8, E366638.8 — Logged by: L. F. Harder
Driller: Ken Arnold — Drill Rig: AP-1000 (No. 57) — Depth to water ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					6	10.	
					6	10.	
					8	11.	
	5				10	11.5	
					11	12.	
					10	12.	
					8	10.5	
					5	10.	
	10				11	11.	
					11	11.5	
					9	10.	
					5	10.	
					3	10.	
	15				9	12.	
					10	11.	
					10	12.	
					12	12.5	
					14	13.	
	20				18	15.	
					20	15.	
					22	15.	
					21	15.	
					23	15.	
	25				26	16.5	
					25	16.	
					22	15.	
					19	14.5	
					17	14.	
	30				17	14.	
					20	16.	
					20	15.	
					18	14.5	
					18	15.	
	35				17	15.	
					17	14.5	
					16	14.5	
					17	14.5	
					19	12.5	
	40				21	15.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC-7 Page 2/ 2

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					21	16.	
					21	16.	
					20	15.5	
					23	15.	
	45				23	16.	
					24	15.5	
					23	16.	
					22	15.5	
					23	16.5	
	50				22	16.5	
					23	16.5	
					23	16.5	
					23	16.	
					22	16.	
	55				21	16.5	
					23	16.	
					23	15.5	
	58				22	16.	

B E C K E R   D R I L L   L O G

Hole No. BOC 86-2
Surf. Elev. 4972 ft.
Max. Depth 68 ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/19/86
Feature Foundation Exploration — Attitude Vertical
Location Ririe Dam - Downstream Flat Area — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water 22 ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4970			<u>0 - 8 feet</u>		9	12.5	Started driving at 8:11 a.m. on 9/19/86 - pulled out at 5 ft. and began new hole due to deflection of casing
			Silty, sandy gravel with cobbles and concrete chunks		14	20.	
		GW,GM			15	15.5	
	5				11	14.	
					12	13.	
					10	12.5	
					11	11.5	
					25	22.	
	10				34	21.5	
			<u>8 - 17 feet</u>		25	19.5	
4960			Similiar to above with subangular to rounded gravel particles		15	16.	
		GW,GM		B-1	10	14.	
					14	16.	
	15				28	20.	
					16	16.5	
					15	16.	
			<u>17 -22 feet</u>		14	15.	
			Sandy silt with some scattered gravel particles		17	17.5	
	20	ML			16	17.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-2 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		ML			15	16.	
4950				B-2	13	15.5	
			22 - 26 feet		12	16.	
		ML	Sandy silt, similiar to above but saturated but with slight amount of wood fragments		15	16.	
	25				22	17.	
					26	17.5	
			26 - 34 feet		18	16.5	
			Gravel - relatively clean, 1/8-inch to 3 inches with 1 inch sizes predominating		19	17.	
					17	17.5	
	30	GP		B-3	25	19.	
					25	18.5	
4940					18	15.5	
					13	17.	
					15	16.5	
	35				15	16.	
					14	15.5	
			34 - 42.5 feet		12	15.	
			Sandy, silty gravel with cobbles - poor recovery		9	14.	
		GM,GW			11	16.	
	40				11	15.5	
					11	16.	
4930					12	16.5	
		SM	42.5 - 43 feet Gravelly, silty sand		54	19.	
					70	23.	
	45		43 - 48 feet - No recovery		68	23.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-2 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					55	21.5	
					25	18.5	
					23	18.5	
			<u>48 - 53 feet</u>		19	18.5	
	50		No recovery		15	18.5	
					15	19.	
4920					20	19.5	
			<u>53 - 55 feet</u> - Basalt fragments with some sand (possibly drove a basalt stone for a few feet before it broke up)		35	21.5	
		GW			80	23.	
	55				50	21.5	
					40	20.5	
			<u>55 - 65 feet</u> Saturated clayey gravel and cobbles - particles are generally broken basalt - possibly residual bedrock surface		27	19.	
					19	18.5	
					19	17.5	
	60	GC		B-4	14	17.	
					16	17.5	
4910					23	18.5	
					23	19.	
					16	18.	
	65				30	19.5	
			<u>65 - 68 feet</u> Saturated clayed gravel and cobbles - particles are generally broken basalt - similiar to above interval		20	17.5	
		GC			21	19.5	
					15	18.5	

Stopped driving at 9:55 a.m. and casing withdrawn by 10:25 a.m. on 9/19/86. Hole backfilled by shovelling cobbles and soil into upper portions of hole up to the surface.

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-2 Page 4/ 4

Weather: Cloudy with occasional showers. Temperature range about 38 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	8 - 17
B - 2	17 - 26
B - 3	26 - 34
B - 4	55 - 65

B E C K E R   D R I L L   L O G

Hole No. BCC 86-3
Surf. Elev. 4971 ft.
Max. Depth 83 ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/17-18/86
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Flat Area	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4970							Started driving at 4:25 p.m. on 9/17/86
					29	18.5	
					38	20.5	
					12	15.	
	5				19	15.5	
					24	16.	
					22	15.5	
					28	15.5	
					59	17.	
	10				31	16.	
4960					18	15.	
					14	15.	
					11	14.5	
					9	14.5	
	15				7	13.	
					7	12.5	
					6	12.5	
					6	12.5	
					7	12.5	
	20				6	13.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-3 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4950					9	15.	
					22	18.	
					27	19.	
					24	18.	
	25				21	17.5	
					18	17.	
					18	17.	
					16	17.	
					11	14.	
	30				9	15.	
4940					11	15.	
					21	18.	
					32	19.5	
					29	18.5	
	35				26	18.5	
					31	19.5	
					36	20.	Stopped driving at 5:10 p.m. on 9/17/86
					53	21.5	
					57	22.5	Restarted driving at 7:32 a.m. on 9/18/86
	40				55	22.5	
4930					76	24.5	
					104	25.5	
					128	25.5	
					134	25.	
	45				149	25.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-3 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					128	24.	
					130	24.	
					168	25.	
					156	25.	
	50				121	24.	
4920					86	22.5	
					64	21.5	
					70	22.5	
					64	22.5	
	55				67	22.5	
					71	22.5	
					45	21.	
					21	18.	
					13	19.5	
	60				26	20.	
4910					26	19.	
					18	17.5	
					13	17.	
					33	19.	
	65				53	21.	
					41	20.5	
					29	22.	
					125	23.5	
					180	23.	
	70				135	22.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-3 Page 4/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4900					100	22.	
					89	21.5	
					107	22.5	
					137	23.	
	75				146	23.5	
					98	22.	
					60	21.5	
					52	21.5	
					42	20.	
	80				29	19.5	
4890					33	20.	
					66	23.5	
	83				230	23.5	Stopped driving at 8:30 a.m. on 9/18/86

Weather: Partly cloudy with slight breeze on both 9/17 and 9/18/86. Temperature range about 38 - 65 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

BECKER DRILL LOG

Hole No. BOC 86-3
Surf. Elev. 4971 ft.
Max. Depth 85 ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/18/86
Feature Foundation Exploration — Attitude Vertical
Location Ririe Dam - Downstream Flat Area — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ≈22 ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4970					14	10	Started driving at 1:30 p.m. on 9/18/86 -
			<u>0 - 5 feet</u> Not logged		5	10.	
					4	15.	
					12	16.5	
	5				9	17.5	
		GW, SW	<u>5 - 7 feet</u> Gravelly sand and sandy gravel		12	13.5	
					13	14.5	
			<u>7 - 11 feet</u>	B-1	15	16.5	
		GM	Silt and gravel		13	14.	
	10				11	16.	
4960					10	15.	
			<u>11 - 15 feet</u>		11	12.5	
		ML, SM	Alternating lenses of sandy silt and silty sand - a few gravel particles and some wood fragments up to 1/2 inches thick	B-2	11	13.5	
					11	13.5	
	15				9	14.	
			<u>15 - 18 feet</u>		11	13.5	
			Moist sandy silt and silty sand with two 1-inch to 2-inch rounded basalt particles		11	13.5	
		ML, SM			10	12.5	
			<u>18 - 21 feet</u>	B-3	10	13.5	
	20		Similiar to above		8	13.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-3 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4950					7	14.	
					7	14.5	
		ML,SM	**21 - 27 feet** Sandy silt and silty sand similiar to 15-21 foot interval but with more gravel particles (.5 - 1 inches) and one 4-in. particle - moister and with branches 1/8 to 3/4 inches thick	B-4	9	12.5	
					7	12.5	
	25				6	13.	
					7	12.5	
					6	13.	
		GM	**27 - 32 feet** free water after adding casing segment - generally poor recovery - silty gravel with rounded gravel particles up to 3 inches in a muddy soup-like slurry	B-5	6	14.	
					15	16.	
	30				15	16.5	
4940					16	17.	
					25	20.	
		GW	**32 - 38 feet** Sandy gravel with rounded particles - maximum particle size greater than 4 inches as evidenced by freshly-broken rounded particles - few fines - no free water (perched water?)	B-6	26	20.	
					29	20.	
	35				34	21.	
					28	20.	
					30	20.	
					50	22.	
		GW	**38 - 42 feet** Sandy gravel similiar to 32-38 ft interval		48	23.5	
	40				48	22.5	
4930					63	22.5	
					60	23.5	
		GW, GW-GM	**42 - 48 feet** Sandy gravel similiar to 32-42 ft interval but with somewhat more non-plastic or low plasticity fines	B-7a	61	22.5	
					61	22.5	
	45				55	21.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-3 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GW,			50	22.	
		GW-GM			45	22.	
					46	22.5	
			48 - 55 feet		57	20.	
	50				26	20.5	
4920			Gravel with less than 15 percent sand - rounded particles with maximum size exceeding 4 inches		26	19.5	
		GP-GW		B-7b	35	22.	
					43	22.	
					40	21.5	
	55		**55 - 56.5 feet**		42	21.5	
		GP	Clean, rounded pea gravel lense with particles 1/4" to 1"		36	20.5	
		GW-GM	**56.5 - 58 feet** Sandy gravel with slight amount of fines - similiar to 42-48 ft.		35	20.5	
					20	18.5	
					29	20.	
	60		**58 - 67 feet**		40	21.	
4910					43	20.	
			Sandy gravel with slight amount of non-plastic fines - similiar to 42-48 ft interval		30	20.	
		GW-GM		B-8	40	20.	
					45	20.	
	65				54	21.	
					45	21.	
					50	21.5	
		GM	**67 - 68 feet** Sandy, silty gravel		47	22.5	
			68 - 71 feet Sandy gravel with slight amount		43	19.5	
		GW-GM	of non-plastic fines - similiar	B-9			
	70		to 56.5-67 ft interval		38	19.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-3 Page 4/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
4900					36	21.5	
			71 - 74 feet				
		GW-GM, GM	Silty, sandy gravel similiar to 56.5-71 ft interval but with more sand and silt	B-10	55	22.	
					72	22.5	
					96	22.5	
		GM	74 - 75 feet Silty, sandy gravel				
	75				83	21.5	
			75 - 78 feet				
		GW	Sandy gravel with rounded particles up to 3 inches - few fines	B-11	50	21.5	
					53	21.5	
					49	20.	
					22	19.	
			78 - 85 feet				
	80		Poor recovery - not logged		33	20.5	
4890					40	21.	
					57	21.5	
					101	23.	Stopped driving at 5:10 p.m.
					150	22.5	- Casing withdrawn by
	85				189	23.	5:45 p.m. on 9/18/86

Weather: Cloudy with slight breeze. Temperature range about 38 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	5 - 11
B - 2	11 - 15
B - 3	15 - 21
B - 4	21 - 27
B - 5	27 - 32
B - 6	32 - 38
B - 7a	42 - 48
B - 7b	48 - 55
B - 8	58 - 67
B - 9	68 - 71
B - 10	71 - 74
B - 11	75 - 78

BECKER DRILL LOG

Hole No. BCC 86-4
Surf. Elev. 4998 ft.
Max. Depth 107 ft.

Project RIRIE DAM SEISMIC STABILITY
Date Drilled 9/19/86
Feature Foundation Exploration
Attitude Vertical
Location Ririe Dam - Downstream Berm
Logged by L. F. Harder
Driller Ken Arnold
Drill Rig AP-1000 (No. 57)
Depth to water ____ ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 11:58 a.m. on 9/19/86
					12	17.	
					13	13.5	
					16	14.5	
	5				17	15.5	
					23	15.5	
					17	14.	
4990					16	14.	
					13	17.5	
	10				11	14.	
					11	13.5	
					13	13.5	
					19	15.5	
					31	18.5	
	15				40	18.	
					45	18.5	
					36	18.	
4980					29	18.5	
					26	18.5	
	20				26	18.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-4 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					29	18.5	
					40	21.	
					37	21.	
					34	20.	
	25				24	19.	
					30	20.5	
					58	22.5	
4970					51	20.5	
					44	22.	
	30				49	22.5	
					34	20.5	
					20	18.	
					19	17.	
					13	15.5	
	35				17	17.5	
					29	20.	
					43	21.5	
4960					34	20.5	
					37	21.5	
	40				52	22.5	
					42	22.	
					44	22.5	
					40	22.	
					34	20.5	
	45				29	20.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-4 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					30	20.5	
					33	20.5	
4950					30	20.	
					50	22.5	
	50				44	22.5	
					38	22.	
					55	22.5	
					70	23.5	
					60	23.5	
	55				56	23.	
					57	24.	
					82	25.	
4940					85	24.5	
					102	24.	
	60				163	25.	
					180	25.5	
					83	24.5	
					71	24.5	
					67	24.5	
	65				66	24.	
					67	24.	
					56	23.5	
4930					45	22.	
					42	22.	
	70				42	22.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-4 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					34	21.5	
					30	21.	
					36	21.5	
					40	22.	
	75				31	21.5	
					48	23.	
					88	24.5	
4920					85	22.5	
					68	22.5	
	80				68	23.	
					84	23.5	
					106	24.	
					124	24.5	
					131	25.	
	85				178	25.5	
					165	25.	
					133	25.	
4910					112	23.	
					106	23.	
	90				126	23.5	
					127	24.	
					126	23.5	
					110	23.	
					114	23.	
	95				83	23.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-4 Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					52	22.5	
					51	22.5	
4900					43	21.	
					40	20.	
	100				58	21.5	
					84	22.	
					105	22.5	
					112	24.5	* *
					107	24.5	* At 107 ft, * pulled casing
	105				218	25.	* up 4.5 ft * and redrove
					290	25.	* 3.5 ft *
	107				312	25.	

Stopped driving at 2:57 p.m. - Casing withdrawn by 3:25 p.m. on 9/19/86

Weather: Cloudy with occasional showers. Temperature range about 38 - 60 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

Redrive

Depth (ft)	N_B	BP (psig)
104	28	22.5
105	27	21.5
106	50	23.

BECKER DRILL LOG

Hole No. BOC 86-4
Surf. Elev. 4999 ft.
Max. Depth 108 ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/26-27/86
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Berm	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			<u>0 - 8 feet</u>				Started driving at 3:55 p.m. on 9/26/86
			Silty, sandy gravel with subangular particles and recently broken cobble fragments.		10	10.5	
					13	11.	
		GM,			11	12.5	
	5	GW-GM			21	17.5	
					20	18.5	
					35	17.	
					18	14.5	
4990					18	16.5	Some contamination from previous holes in 0-18 ft interval
	10		<u>8 - 18 feet</u>		19	17.	
			Silty, sandy gravel with subangular particles and recently broken cobble fragments.		17	16.	
		GM,			63	19.	
		GW-GM	Similiar to 0-8 ft interval but with more recent angular cuttings from broken cobbles		45	20.	
					22	16.5	
	15				17	16.5	
					28	19.	
					41	21.	
					52	21.5	
4980			<u>18 - 22 feet</u>		42	19.	
	20		Poor recovery		25	17.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-4 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					40	19.	Sampling hose found to be plugged with cobbles at 22' -hose unplugged
					57	21.5	
			22 - 28 feet		57	20.5	
			Silty, sandy gravel and broken cobble fragments - gravel and cobble particles generally subangular to angular.		59	21.	
	25	GW-GM		B-1	48	20.5	
					40	19.5	
					37	19.5	
					32	19.	
4970					45	20.	
	30		**28 - 36 feet**		46	20.	
			Silty, sandy gravel and broken cobble fragments - gravel and cobble particles generally subangular to angular. Similiar to 22-28 ft interval.		41	20.	
		GW-GM		B-2	44	20.	
					37	19.5	
					23	18.5	
	35				17	16.	Stopped driving at 4:45 p.m. on 9/26/86
					25	17.5	
			36 - 43 feet		30	18.5	Restarted driving at 9:50 a.m. on 9/27/86
			Silty, sandy gravel with subrounded to subangular particles with recently broken cobble fragments. Somewhat more sand and silt than 22-36 ft interval.		34	19.5	
4960					40	21.5	
	40	GW-GM		B-3	28	20.5	
					32	20.5	
					65	23.5	
					63	20.5	
					30	17.5	
	45	ML			24	17.	

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		ML	43 - 48 feet Moist sandy silt with subrounded cobbles together with wood and root fragments (1/8" to 3/8" diam)	B-4	24	17.5	
					27	16.5	
					31	17.5	
4950		ML	48 - 50 feet Moist sandy silt with subrounded cobbles - similiar to 43-50 ft		35	19.5	
	50				20	18.	
		GW	50 - 56 feet Sandy gravel with few fines. Particles generally subrounded with maximum particle size about 2 inches.	B-5	28	18.5	
					49	19.5	
					43	19.	
					45	19.	
	55				44	19.	
		GW	56 - 58 feet Sandy gravel with few fines. Particles generally subrounded with max. size about 2 inches. Similiar to 50-56 ft interval.		45	18.5	
					42	18.	
					37	19.5	
4940		GW-GM, GM	58 - 64 feet Silty, sandy gravel and cobbles. Gravel and cobble particles are generally subrounded or broken subrounded - occaisonal sandy silt lenses with small root fibers.	B-6	73	20.	
	60				80	20.5	
					75	19.5	
					80	20.5	
					102	20.5	
					90	20.	
	65	GW-GM, GM	64 - 66 feet Silty, sandy gravel and cobbles. Similiar to 58-64 ft interval.		60	19.5	
					45	19.5	
		ML-GM	66 - 71 feet Gravelly, sandy silt with rounded cobbles to 3 inches. free water in casing at 68 feet after adding casing segment.		30	18.	
					15	16.	
4930					12	17.5	
	70				25	15.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-4 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		ML-GM			24	18.5	
			71 - 78 feet		44	19.	
			Saturated gravel and cobbles with small sand and fines content.		50	18.5	
		GP-GW	Gravel and cobble particles are subrounded to subangular and range	B-7	33	18.5	
	75		up to one 4-inch broken subrounded cobble.		57	20.	
					75	20.	
			No free water in casing at 78 feet after adding new casing segment.		90	20.5	
					93	20.	
4920					78	19.5	
	80		78 - 88 feet		76	19.	
			Saturated gravel and cobbles with small sand and fines content.		60	19.	
			Gravel and cobble particles are subrounded to subangular.		34	18.	
		GP-GW		B-8	25	17.5	
			Similiar to 71-78 ft interval but with several 3 to 4-inch		24	17.	
	85		subangular particles suggesting that drill bit cut larger cobbles.		84	19.5	
					120	20.	
			No free water in casing at 88 feet after adding new casing segment.		134	19.5	
					174	19.5	
4910					140	20.5	
	90		88 - 96 feet		135	21.	
			Silty, sandy gravel - similiar to 78-88 ft interval but with more sand and silt content.		170	20.5	
		GW-GM	Maximum particle size about 2.5 inches.	B-9	130	20.	
					170	20.5	
					192	21.	
	95				132	20.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-4 Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GW-GM			123	20.	
			96 - 99 feet		140	20.	
		GW-GM	Silty, sandy gravel with rounded gravel particles. Somewhat lower fines content than 88-96 ft interval.	B-10	150	20.5	
4900					100	20.5	
	100				110	21.	
			99 - 108 feet		103	21.	
			Gravelly sand together with sandy subangular to subrounded 2-inch gravel. Relatively small fines content.		106	21.	
					140	21.	
		SW-GW		B-11	187	21.	
	105				260	20.5	
					340	21.	
					320	21.5	
	108				220	21.	

Stopped driving at 10:45 a.m. - Casing withdrawn by 11:20 a.m. on 9/27/86.

Weather: Cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	22 - 28
B - 2	28 - 36
B - 3	36 - 43
B - 4	43 - 48
B - 5	50 - 56
B - 6	58 - 64
B - 7	71 - 78
B - 8	78 - 88
B - 9	88 - 96
B - 10	96 - 99
B - 11	99 - 108

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

B E C K E R   D R I L L   L O G

Hole No. BCC 86-5
Surf. Elev. 4995 ft.
Max. Depth 99.7 ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/19-20/86
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Berm	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 4:18 p.m. on 9/19/86
					17	14.5	
					11	12.	
					9	11.	
4990	5				9	11.5	
					10	12.5	
					10	11.5	
					7	6.5	
					12	12.5	
	10				26	19.	
					30	19.5	
					24	17.5	
					15	14.5	
					14	14.5	
4980	15				9	15.	
					10	13.	
					8	13.5	
					7	8.	
					16	19.	
	20				22	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-5 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					20	16.5	
					18	17.	
					16	16.5	
					29	19.	
4970	25				24	17.	
					23	17.	
					25	17.	
					17	16.	
					15	16.	
	30				15	15.5	
					17	16.5	
					14	15.5	
					29	18.5	
					29	18.5	
4960	35				26	18.5	
					37	19.5	
					50	21.	
					49	20.5	
					31	19.	
	40				22	17.5	
					22	17.5	
					22	18.	
					23	18.	
					24	18.	
4950	45				24	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-5 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					24	18.	
					22	18.	
					21	17.5	
					21	18.	
	50				26	18.5	
					23	18.5	
					25	18.5	
					29	19.5	
					35	20.	
4940	55				34	19.5	
					31	18.	
					31	18.5	
					41	19.5	
					51	20.5	
	60				62	19.5	
					80	20.	
					104	20.	
					140	18.	
					156	21.	
4930	65				173	20.5	
					142	20.	Stopped driving at 5:30 p.m. on 9/19/86
					167	20.	
					213	21.5	Restarted driving at 7:32 a.m. on 9/20/86
					246	21.	
	70				273	20.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-5 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					252	21.	
					254	21.5	
					189	22.5	
					160	24.5	
4920	75				118	23.5	
					155	23.5	
					132	22.5	
					131	22.	
					75	18.	
	80				41	19.	
					32	21.	
					37	20.5	
					44	20.	
					34	20.5	
4910	85				32	21.	
					40	20.5	
					50	21.5	
					37	17.5	
					37	18.	
	90				38	19.	
					48	21.5	
					60	23.	
					105	22.	
					135	23.	
4900	95				104	24.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-5 Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					174	23.	
					210	23.	* At 99.7 ft, * casing raised
					258	23.	* 3 ft and * redriven
					448	24.	* 2.8 ft *
	100				500+	21.5	500 for 8 in.

Stopped driving at 8:58 a.m. - Casing withdrawn by 9:37 a.m. on 9/20/86

Weather: Cloudy with occasional showers. Temperature range about 38 - 60 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

Redrive

Depth (ft)	N_B	BP (psig)
97	22/9 in.	15.5
98	31	18.
99	34	19.

B E C K E R D R I L L L O G

Hole No. BOC 86-5
Surf. Elev. 4995 ft.
Max. Depth 92.5 ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/20/86
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Berm	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	46 ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			<u>0 - 8 feet</u>		5	15.	Started driving at 10:42 a.m. on 9/20/86
			Slightly moist silty, sandy gravel with some broken cobble pieces. Gravel particles are subangular to angular in shape.		12	15.	
		GW-GM		B-1	11	15.	
4990	5				8	13.	
					6	13.	
					8	13.5	
					10	15.	
			<u>8 - 16 feet</u>		11	17.5	
	10		Slightly moist silty, sandy gravel with some broken cobble pieces. Similiar to above but with more broken cobble fragments (broken angular particles from 1 to 4 inches in diameter)		24	19.	
					23	18.5	
		GW-GM		B-2	21	19.	
					27	19.5	
					22	18.5	
4980	15				29	19.5	
			<u>16 - 18 feet</u> Slightly moist silty, sandy gravel. Similiar to 8-16 ft interval but with more sand and few gravel-sized particles above 1-1/2 in.(save one 4-in. particle)		28	18.5	
		GW-GM			26	17.5	
					19	18.	
		GW-GM			23	19.5	
	20				22	19.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-5 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					20	17.5	
			<u>18 - 28 feet</u> Slightly silty, sandy gravel with broken cobble fragments. Similiar to 8-16 ft interval but with more sand and somewhat smaller amount of fines.		18	17.5	
					21	18.	
		GW-GM		B-3	18	17.	
4970	25				24	18.5	
					29	19.5	
					37	19.5	
					35	19.5	
			<u>28 -38 feet</u> Silty, sandy gravel with broken cobble fragments. Similiar to 8-16 ft interval but with somewhat more fines content.		30	18.5	
	30				15	17.5	
					24	20.5	
					26	20.	
		GW-GM		B-4	26	18.	
					16	16.5	
4960	35				17	17.	
					19	18.5	
					14	18.5	
					17	18.	
			<u>38 - 42 feet</u> No recovery		16	17.5	
	40				15	17.5	
					12	17.	
					11	15.	
			<u>42 - 48 feet</u> Sandy silt with occasional gravel and 4-in. cobble particles. - Saturated after 46 ft.		12	16.	
		ML		B-5	15	15.5	
4950	45				8	15.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-5 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					9	15.5	
		ML			7	15.	
					7	16.	
					12	15.	
	50		**48 -58 feet** Sandy silt with occasional pea gravel (1/2" to 1") and cobble (4") particles together with a few pieces of wood or root fragments up to 3/8" thick. Silt appears similiar to 42-48 ft interval except somewhat stiffer		8	14.5	
					8	14.5	
					10	15.	
		ML		B-6	9	14.5	
					11	14.5	
4940	55				15	13.5	
					14	13.5	
			At 58 ft, free water found in casing after adding new casing segment.		14	12.5	
			58 - 59 feet Silt and gravel mixture obscured by water. After 59 ft, free water stopped flowing up.		18	15.	
					38	21.5	
	60				46	21.5	
			59 - 65 feet		50	21.5	
		GP-GW	Clean gravel and broken cobbles. Particles are wet and rounded - range from 1/8" to 3" (broken rounded cobbles) with predominant size about 1 inch.	B-7	50	20.5	
					67	23.	
					110	23.5	
4930	65		**65 - 68 feet** Silty, sandy gravel with broken rounded cobbles. Similiar to 59-65 ft interval but with more fine sand and silt. At 67 ft, soil became dryer - could be air-dried by blower due to high blowcount in this interval? At 68 ft, no free water in casing after adding new casing segment.		100	23.5	
					218	25.	
		GW-GM		B-8	335	25.	
					265	25.5	
					170	23.5	
		GW-GM		B-9			
	70				170	22.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-5 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		cobbles	68 - 71 feet Moist sandy gravel with small fines content. Similiar to	B-10	150	22.	
			65-68 ft interval but with a larger percentage of particles		125	24.	
			having sharp angles/edges which suggests that large cobbles are		114	23.5	
		GW-GM	being cut. Particles less than about 1 in. are generally	B-11	78	23.5	
4920	75		angular to subrounded - most appear to be broken rounded		63	23.	
			particles. 71 feet A lens of 1" to 4"		66	22.5	
			cobbles. 71 - 78 feet		50	22.5	
			Moist sandy gravel with small fines content. Similiar to 68-71		42	21.5	
			ft interval but with more large gravel-sized particles. At 78 ft,		50	20.5	
	80		free water was found in casing after adding new casing segment.		15	20.5	
			78 - 82 feet Poor recovery, mostly water.		23	20.	
					30	20.	
			82 - 88 feet		12	19.	
			Saturated, clayey sand coating large gravel and broken cobble		13	19.	
4910	85	GC-GW	particles. Cobble particles are subangular in shape.	B-12	12	19.5	
					13	18.	
			At 88 ft, free water was found in casing after adding new casing		11	18.	
			segment.		12	19.	
			88 - 91 feet Saturated, clayey sand coating		20	19.5	
	90	GC-GW	large gravel and broken cobble particles. Similiar to 82-88 ft		47	21.	
			interval. 91 - 92.4 feet		35	20.	
		GC-GW/ bedrock	Subangular and angular black basalt (fresh appearance) gravel	B-13	200	24.5	
	93		and cobble-sized particles with clayey sand matrix (bedrock?).		1000+	25.5	1000 for 6 in.

Stopped driving at 1:10 p.m. - Casing withdrawn by 1:50 p.m. on 9/20/86.

Weather: Cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	0 - 8
B - 2	8 - 16
B - 3	18 - 28
B - 4	28 - 38
B - 5	42 - 48
B - 6	48 - 58
B - 7	59 - 65
B - 8	65 - 68
B - 9	68 - 71
B - 10	71
B - 11	71 - 71
B - 12	82 - 88
B - 13	91 - 92.4

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

BECKER DRILL LOG

Hole No. BCC 86-6
Surf. Elev. 4995 ft.
Max. Depth 82.5 ft.

Project: RIRIE DAM SEISMIC STABILITY
Date Drilled: 9/22/86
Feature: Foundation Exploration
Attitude: Vertical
Location: Ririe Dam - Downstream Berm
Logged by: L. F. Harder
Driller: Ken Arnold
Drill Rig: AP-1000 (No. 57)
Depth to water: ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 7:57 a.m. on 9/22/86
					24	18.5	
					19	19.5	
					21	17.5	
4990	5				14	18.5	
					18	17.	
					20	18.	
					27	20.5	
					42	22.5	
	10				25	19.5	
					16	17.	
					20	19.	
					17	21.	
					35	20.	
4980	15				41	22.	
					34	22.5	
					47	25.	
					54	25.5	
					38	22.	
	20				41	22.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-6 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					41	22.5	
					70	25.	
					81	25.	
					87	25.	
4970	25				75	23.5	
					65	23.	
					78	24.	
					65	23.	
					40	21.	
	30				31	20.	
					28	20.	
					25	20.	
					29	20.	
					46	23.	
4960	35				21	19.5	
					24	20.5	
					25	20.5	
					28	21.	
					38	22.	
	40				24	20.	
					19	18.5	
					14	17.5	
					10	16.5	
					8	16.	
4950	45				8	15.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-6 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					6	15.	
					6	15.	
					7	15.	
					8	15.	
	50				7	14.5	
					7	15.	
					32	20.	
					22	19.	
					12	16.5	
4940	55				30	20.	
					142	23.5	
					212	25.	
					104	21.	
					44	21.	
	60				14	18.	
					17	18.5	
					31	20.	
					19	19.	
					10	17.	
4930	65				12	17.5	
					9	18.	
					13	18.5	
					18	18.	
					13	18.5	
	70				10	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-6 Page 4/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					11	18.	
					11	18.	
					12	18.5	
					14	19.	
4920	75				11	19.	
					13	18.5	
					13	18.5	
					17	19.	
					92	23.	
	80				89	23.5	* At 82.5 ft, * raised casing
					216	25.	* 3.5 ft and * redrove 3 ft
					870	25.5	* *
	83				1000+	25.5	1000 for 6 in.

Stopped driving at 9:48 a.m. - Casing withdrawn by 10:20 a.m. on 9/22/86

Weather: Clear and cold with slight breeze. Temperature range about 30 - 45 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

Redrive

Depth (ft)	N_B	BP (psig)
80	11	17.5
81	8	18.
82	9	17.5

BECKER DRILL LOG

Hole No. BOC 86-6
Surf. Elev. 4995 ft.
Max. Depth 60. ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/22/86
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Berm	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					12	16.	Started driving at 11:40 a.m. on 9/22/86
			0 - 8 feet		17	17.5	
			Slightly moist silty, sandy gravel with broken cobble particles. Cobble-size particles are generally subangular to angular indicating that they have been broken from larger particles during either driving or during construction.		16	16.5	
					14	15.5	
4990	5	GW-GM		B-1	17	16.	
					22	17.5	
					32	19.5	
					44	21.	
			8 - 14 feet		25	21.	
	10		Slightly moist silty, sandy gravel with broken cobble particles. Cobble-size particles are generally subangular to angular indicating that they have been broken from larger particles. Similiar to 0-8 ft interval but with moare sand.		19	19.	
		GW-GM		B-2	25	20.5	
					21	18.5	
					21	18.	
			14 - 21 feet		26	20.5	
4980	15		Slightly moist silty, sandy gravel with broken cobble particles. Gravel and cobble-sized particles appear to be broken basalt particles dark gray to black in color. Similiar to 8-14 ft interval.		26	20.5	
					35	22.	
		GW-GM		B-3	46	22.5	
					35	22.	
					33	21.5	
	20				31	21.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-6 Page 2/ 3

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GW-GM					
		GW-GM	**21 - 28 feet** Slightly moist silty, sandy gravel with broken cobble particles. Similiar to 14-21 ft interval but with somewhat lesser amount of sand and fines content. Gravel and cobble-sized particles remain generally subangular indicating broken particles (probably during construction).	B-4	34	20.5	
					40	22.	
					46	23.	
					56	23.5	
4970	25				40	22.	
					37	20.5	
					27	20.5	
		GW-GM	**28 - 33 feet** Slightly moist silty, sandy gravel with broken cobble particles. Similiar to 21-28 ft interval.	B-5	26	21.	
					35	22.	
	30				37	22.5	
					29	21.5	
					29	21.	
		GW-GM	**33 - 39 feet** Silty, sandy gravel with broken cobble particles. Similiar to 21-33 ft interval. At 35 ft, some particles change from slightly moist to wet. In addition, many 4-in. broken particles.	B-6	25	19.5	
					22	19.5	
4960	35				23	19.5	
					21	20.5	
					35	22.5	
					53	24.	
		GW-GP	**39 - 44 feet** Slightly moist sandy gravel with fewer fines than above. Gravel particles mostly intact and broken subrounded in shape (alluvium?). Maximum particle size about 3 in.	B-7	50	22.5	
	40				40	21.	
					30	21.	
					29	21.	
					19	19.	
		GP			17	18.5	
4950	45				19	18.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-6 Page 3/ 3

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			44 - 48 feet				
					23	20.	
		GP	Poor recovery. Mostly rounded	B-8			
			gravel and broken rounded cobble		25	19.5	
			particles.				
					35	21.	
			At 48 ft, free water found in				
			casing after adding new casing		32	20.5	
			segment.				
	50	GP	48 - 52 feet		36	21.	
			Poor recovery. Mostly rounded				
			gravel and broken rounded cobble		32	20.	
			particles.				
			52 - 54 feet		23	19.	
			Wet broken basalt particles				
		GP	between 1/4" to 4" in size.	B-9	165	24.5	BEDROCK?
		bedrock?	Small sand or fines content.				
					90	24.5	
			54 - 58 feet				
4940	55		Wet broken basalt particles		140	25.5	
			similiar to 52-54 ft interval				
		GP	but with some sandy silt/silty	B-10	490	26.	
		bedrock?	sand coatings on particles.				At 57.5 ft,
					600	24.5	work stopped
			At 57.5 ft, free water found in				between 1:15
			casing after work stoppage. At		300	26.	and 2:35 p.m.
			58 ft, free water found in casing				to repair
			after adding new casing segment.		730	25.	hydraulic hose
		GP	58 - 60 feet Wet broken basalt				
	60	bedrock?	particles with trace of silty sand-		1450	26.	
			/sandy silt coatings.				

Stopped driving at 3:06 p.m. - Casing withdrawn by 3:30 p.m. on 9/22/86.

Weather: Clear with slight breeze. Temperature range about 40 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	0 - 8
B - 2	8 - 14
B - 3	14 - 21
B - 4	21 - 28
B - 5	28 - 33
B - 6	33 - 39
B - 7	39 - 44
B - 8	44 - 48
B - 9	52 - 54
B - 10	54 - 58

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

B E C K E R   D R I L L   L O G

Hole No. BOC 86-6B
Surf. Elev. 4995 ft.
Max. Depth 107. ft.

Project: RIRIE DAM SEISMIC STABILITY — Date Drilled: 9/22-23/1986
Feature: Foundation Exploration — Attitude: Vertical
Location: Ririe Dam - Downstream Berm — Logged by: L. F. Harder
Driller: Ken Arnold — Drill Rig: AP-1000 (No. 57) — Depth to water: ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GW-GM	**0 - 8 feet** Silty, sandy gravel. Particles are up to 4 in. in size and are generally subangular in shape. Larger particles appear to be broken from still larger particles either during drilling or from construction.		10	13.	Started driving at 3:57 p.m. on 9/22/86
					15	15.	
					12	14.5	
4990	5	GW-GM		B-1	12	14.5	
					12	15.	
					8	13.	
					10	13.	
					10	14.	
	10	GW-GM	**8 - 18 feet** Silty, sandy gravel - generally poor recovery. Soil similiar to 0-8 ft interval except that maximum particle size is less than about 2 in.		10	15.	
					7	14.	
					9	14.	Poor recovery may be due to driving cobble in front of bit
				B-2	8	14.	
					10	13.5	
4980	15				5	12.5	
					7	15.	
					10	15.5	
			18 - 23 feet		20	19.	
		GW-GM	Slightly moist - almost dry broken subangular gravel and cobble particles with silty sand.	B-3	27	13.5	
	20				32	19.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-6B Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					38	19.5	
		GW-GM		B-3	25	20.5	
					28	20.	
			<u>23 - 29 feet</u>		34	20.5	
4970	25		Slightly moist - almost dry broken subangular gravel and cobble particles together with silty sand. Similiar to 18-23 ft interval.		30	21.	
		GW-GM		B-4	25	21.	
					23	19.5	
					24	20.5	
					30	19.5	
	30		<u>29 - 34 feet</u>		16	19.	
			Slightly moist broken subangular gravel and cobble particles together with silty sand. Similiar to 18-29 ft interval.		13	16.	
		GW-GM			7	15.	
			Particles become wet at 34 ft. (perched water?)		7	15.	
					12	15.	
4960	35		<u>34 - 38 feet</u>		24	18.5	
		GW-GM	Moist to saturated silty, sandy gravel with numerous 4-in. broken cobbles (appear freshly broken by bit). Somewhat similiar to 18-34 ft interval but with more sandy silt.	B-5	22	19.	
					22	19.	
					24	20.	
			<u>38 - 43 feet</u>		33	19.	
	40		Broken basalt cobble and gravel particles together with sandy silt balls.		30	20.5	
		GM		B-6	22	19.	
			<u>43 - 47 feet</u>		24	19.5	
			Broken basalt cobble and gravel particles together with some sandy silt balls. Poor recovery. Similiar to 38-43 ft interval but with more 3-in. basalt fragments.		17	18.5	
		GM-GW		B-7	21	18.	
4950	45				20	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-6B Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GM-GW		B-7	15	17.5	
					16	17.5	
			47 - 54 feet		14	17.	
			Saturated sandy silt with occasional broken basalt cobbles and gravel particles together with a few 3/8 to 1/2-in. wood or tree branch/root pieces.		14	16.5	
	50				9	15.5	
		ML		B-8	10	16.5	
			Stopped driving briefly at 54 ft. Free water in casing after resuming air recirculation		9	16.	
					11	15.	
			54 - 56 feet		15	16.	
4940	55	ML	Saturated sandy silt with occasional broken basalt cobbles and gravel particles together with a few 3/8 to 1/2-in. wood pieces. Similiar to 47-54 ft interval.		23	13.5	
					38	18.5	
		GP-GW	56 - 58 feet	B-9	37	19.5	Stopped driving at 5:40 p.m. on 9/22/86.
			Clean, rounded gravel with small sand and fines content together with broken basalt cobble pieces.		29	19.	
					32	21.	Started driving at 7:45 a.m. on 9/23/86
	60		At 58 ft, free water found in casing after adding new casing segment.		35	16.5	
		GP-GW		B-10	10	16.	
			58 - 64 feet		10	19.	
			Relatively clean subrounded to subangular gravel with small sand and fines contents transitioning to silty gravel. At 64 ft, silt balls are found.		25	19.5	
					12	18.	
4930	65				7	14.	
		GM-GW	64 - 68 feet Silty, sandy gravel - very soupy return with maximum particle size about 2 in.	B-11	5	13.5	
			At 68 ft, free water found in casing after adding new casing segment.		17	16.	
					27	17.5	
					15	18.	
		SW-GW		B-12			
	70				21	16.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-6B Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			68 - 74 feet		34	18.	
		SW-GW	Gravelly sand/sandy gravel. Gravel particles are subrounded and are mixed with subangular and angular cobble fragments. Small fines content.	B-12	22	17.5	
					13	16.	
					15	16.5	
4920	75		No recovery 74-78 ft. Stopped driving at 78 ft and used loading poles to find bit blocked with cobble. Unplugged bit and then raised casing back up to 74 ft and redrove back to 78 ft.		15	17.5	
		SW		B-13	14	17.	
					15	17.	
			REDRIVE 74 - 78 feet Gravelly sand. Similiar to 68-74 ft interval but with much smaller gravel and cobble contents		21	17.	
		SW			14	17.	
	80		At 78 ft, free water found in casing after adding new casing segment.		33	17.5	
					46	18.5	
		GW-GM	78 - 80 feet Gravelly sand similiar to 74-78 ft interval.		89	19.	
			80 - 84 feet Silty, sandy gravel with subrounded and broken subrounded cobble particles.		83	20.	
					57	19.5	
4910	85		84 - 88 feet		34	18.5	
		CL	Silty clay with some broken basalt particles (weathered rock?)	B-14	15	17.	
			At 88 ft, no free water found in casing after adding new casing segment.		14	17.	
					12	17.5	
		CL	88 - 90 feet Silty clay with little gravel or cobble particles.	B-15	25	17.	
	90				25	20.	
			90 - 98 feet		47	20.5	
			Broken basalt fragments together with brown clayey sand. Basalt fragments range up to 4 in. (bedrock?)		63	21.	
		GC bedrock?		B-16	34	19.5	
					28	19.	
4900	95				23	18.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-6B Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GC bedrock?		B-16	22	19.	
					21	18.5	
			At 98 ft, no free water found in casing after adding new casing segment.		19	18.5	
					17	19.	
			98 - 104 feet				
	100				20	19.5	
		GC bedrock?	Broken basalt fragments together with clayey sand. Basalt particles range up to 4 in. (bedrock?) Similiar to 90-98 ft interval.	B-17	27	19.	
					28	19.	
					30	19.5	
			104 - 107 feet		44	20.5	
4890	105				48	20.	
		GC bedrock?	Broken basalt fragments together with clayey sand. Basalt particles range up to 4 in. (bedrock?) Similiar to 90-104 ft interval but with numerous 3/4 to 1-1/2 in. weathered basalt nuggets	B-18	115	21.	
					800	23.	

Stopped driving at 10:15 a.m. - Casing withdrawn by 10:50 a.m. on 9/23/86.

Weather: Clear with slight breeze, some high clouds on 9/23/86. Temperature range about 29 - 70 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	3 - 8
B - 2	8 - 18
B - 3	18 - 23
B - 4	23 - 29
B - 5	34 - 38
B - 6	38 - 43
B - 7	43 - 47
B - 8	47 - 54
B - 9	56 - 58
B - 10	58 - 64
B - 11	64 - 68
B - 12	68 - 74
B - 13	74 - 78
B - 14	84 - 88
B - 15	88 - 90
B - 16	90 - 98
B - 17	98 - 104
B - 18	104 - 107

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

BECKER DRILL LOG

Hole No. BCC 86-7
Surf. Elev. 4995 ft.
Max. Depth 97. ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/23/1986
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Berm	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 11:54 a.m. on 9/23/86
					23	13.5	
					40	14.	
					38	13.	
4990	5				25	10.5	
					25	12.5	
					19	11.	
					10	9.5	
					18	13.5	
	10				19	15.5	
					49	15.	
					31	13.5	
					23	13.	
					17	13.	
4980	15				12	12.5	
					10	10.5	
					11	13.	
					13	14.5	
					17	16.5	
	20				29	18.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-7 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					30	18.	
					27	17.5	
					24	17.	
					41	20.5	
4970	25				38	20.	
					53	22.	
					65	23.	
					64	22.	
					50	21.	
	30				20	18.	
					22	18.	
					175	25.5	
					72	23.5	
					46	22.	
4960	35				33	20.5	
					35	21.	
					29	22.	
					46	21.	
					43	19.5	
	40				26	19.	
					24	19.5	
					27	19.5	
					27	19.	
					26	19.	
4950	45				23	19.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-7 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					22	19.5	
					28	20.	
					35	20.5	
					31	21.5	
	50				36	22.	
					37	22.	
					36	22.	
					37	23.5	
					51	24.5	
4940	55				77	24.	
					80	23.5	
					71	22.	
					62	21.5	
					44	22.5	
	60				59	24.	
					150	24.	
					143	24.5	
					110	23.5	
					70	22.	
4930	65				59	23.	
					46	23.	
					56	23.5	
					61	22.	
					81	23.	
	70				115	24.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-7 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					115	24.	
					123	24.	
					120	24.5	
					120	24.5	
4920	75				108	24.5	
					94	24.	
					84	24.	
					98	23.	
					107	23.5	
	80				121	23.	
					142	24.5	
					205	24.5	
					290	24.	
					310	24.5	
4910	85				250	24.5	
					255	25.	
					288	25.	
					214	24.	
					138	23.	
	90				121	23.	
					145	23.	
					185	23.	
					183	24.	
					203	25.	
4900	95				170	24.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-7 Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							* At 97 ft,
					195	24.	* casing raised
							* 2.5 ft and
	97				200	24.	* redriven
							* 2.5 ft

Stopped driving at 2:10 p.m. - Casing withdrawn by 2:40 p.m. on 9/23/86

Weather: Clear with slight breeze and some high clouds Temperature range about 40- 60 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

<u>Redrive</u>

Depth (ft)	N_B	BP (psig)
95	9/6 in.	17.5
96	15	19.5
97	20	21.

B E C K E R   D R I L L   L O G

Hole No. BOC 86-7
Surf. Elev. 4994 ft.
Max. Depth 98. ft.

Project	RIRIE DAM SEISMIC STABILITY	Date Drilled	9/25/86
Feature	Foundation Exploration	Attitude	Vertical
Location	Ririe Dam - Downstream Berm	Logged by	L. F. Harder
Driller	Ken Arnold Drill Rig AP-1000 (No. 57)	Depth to water	ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			<u>0 - 8 feet</u>		13	9.	Started driving at 12:25 p.m. on 9/25/86
			Not logged due to presence of cuttings from previous BOC sounding in pipe.		14	11.5	
					15	10.	
4990					15	8.	
	5				10	12.	
					10	11.	
					12	13.	
					14	12.	
			<u>8 - 14 feet</u>		20	15.	
	10		Moist silty, sandy gravel and broken basalt cobbles. Gravel and cobble particles are subangular to angular and have fresh fractures (indicating bit cut pieces from larger particles). One 4-in. particle.		15	16.	
		GW-GM		B-1	13	16.	
					20	17.	
					19	16.5	
4980					17	16.	
	15		<u>14 - 19 feet</u>		20	17.	
			Moist silty, sandy gravel and broken basalt cobbles. Gravel and cobble particles are mostly subangular to angular and have fresh fractures. Similiar to 8-14 ft interval but with some occasional subrounded gravel particles.		30	18.	
		GW-GM		B-2	26	17.5	
					15	15.	
					17	16.	
	20	GW-GM		B-3	15	14.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-7 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			<u>19 - 25 feet</u> Poor recovery		26	16.	Driving cobble?
			<u>19 - 28 feet</u>		17	16.	
			Silt, sandy gravel and broken basalt particles. Gravel and cobble particles are generally subangular to angular with occasional subrounded particles. Similiar to 14-19 ft interval but with some lenses of sandy silt. At 28 ft, some particles are wet.		20	16.	
4970		GW-GM		B-3	27	17.5	
	25				23	16.5	
					29	17.5	
					37	19.	
					37	19.	
			<u>28 - 36 feet</u>		35	30.	
	30		Fair recovery. Mostly subangular to angular gravel and broken basalt particles with a slight amount of sand with few fines.		30	17.5	
					25	20.5	
		GW-GP		B-4	56	21.	
					46	20.5	
4960					56	21.5	
	35				55	22.	
			<u>36 - 39 feet</u>		45	21.5	
			Subangular to angular broken basalt cobbles mixed together with sandy silt. (transition between materials?)		46	23.5	
		GM-GW		B-5	65	23.5	
			<u>39 - 48 feet</u>		39	20.	
	40				31	20.	
			Moist sandy silt with occasional small gravel together with 1/8 in. diameter roots and wood fragments. Becomes saturated at 44 feet.		31	20.	
		ML		B-6	30	19.5	
					30	19.	
4950					26	18.5	
	45				24	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-7 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		ML		B-6	22	18.	
					19	18.	
		GM	48 - 49 feet Wet silty gravel.		25	19.	
					24	19.	
	50	GP-GW	49 - 56 feet Wet subrounded gravel and broken subrounded cobble pieces together with a small sand and silt content. Occasional silty sand lenses.	B-7	27	19.	
					30	20.	
					23	19.5	
					28	19.5	
4940					40	21.5	
	55				69	23.	
		GW	56 - 58 feet Wet subrounded gravel and broken subrounded cobble pieces together with silty sand.		70	23.5	
					78	23.	
					88	23.	
		GW-GP	58 - 68 feet Wet subrounded and broken subrounded gravel particles 1/8" to 3". Small sand and fines contents.	B-8	89	22.5	
	60				108	23.	
					110	23.	
					100	22.5	
					60	21.	
4930					50	22.	
	65				50	21.5	
					45	20.5	
					44	22.	
		GW-GM	68 - 71 feet Silty, sandy gravel similiar to 58-68 ft interval but with more silty sand.		55	22.	
					39	21.	
	70				14	19.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-7 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					35	22.5	
			<u>71 - 75 feet</u>		58	21.5	
		SW-GW SM-GM	High water content recovery (soupy mix) of subrounded gravelly and cobblely sand with some silt fines	B-9	60	22.	
4920					75	23.	
	75		<u>75 - 78 feet</u>		95	23.5	
		GW-GP	Wet (no soupy mix) subrounded gravel and cobbles with slight amount of sand and silt.		84	23.	
				B-10	75	23.	
					60	21.5	
			<u>78 - 88 feet</u>		40	20.	
	80		Wet subrounded gravel and cobbles together with relatively clean sand. Relatively small amount of fines. Similiar to 75-78 ft interval.		40	21.5	
					85	22.5	
					80	23.5	
		GW-GP		B-11	88	24.	
4910					93	24.	
	85				120	24.5	
					119	24.	
					110	24.	
					115	24.5	
			<u>88 - 95 feet</u>		103	23.5	
	90		Wet sandy gravel and cobbles. Gravel and cobble particles are mostly subrounded. Similiar to 75-88 ft intervals but with more sand.		95	23.	
					87	23.	
		GW		B-11	73	23.	
					100	23.5	
4900					104	23.	
	95				90	23.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-7 Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			95 - 98 feet		84	23.	
		GW	Wet sandy gravel together with several 4-in. broken subrounded basalt particles.	B-12	74	23.	
	98				90	23.5	

Stopped driving at 2:45 p.m. - Casing withdrawn by 3:45 p.m. on 9/25/86.

Weather: Cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	8 - 14
B - 2	14 - 19
B - 3	36 - 43
B - 4	28 - 36
B - 5	36 - 39
B - 6	39 - 48
B - 7	49 - 56
B - 8	58 - 68
B - 9	71 - 75
B - 10	75 - 78
B - 11	78 - 88
B - 12	95 - 98

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

B E C K E R   D R I L L   L O G

Hole No. BCC 86-8
Surf. Elev. 4994 ft.
Max. Depth 90. ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/23-25/86
Feature Foundation Exploration — Attitude Vertical
Location Ririe Dam - Downstream Berm — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 5:05 p.m. on 9/23/86
					22	17.	
					16	14.5	
4990					14	14.	
	5				13	13.	
					26	16.	
					44	17.	
					48	18.	
					37	14.	
	10				31	14.5	
					16	12.5	
					16	12.	
					19	13.5	
4980					23	12.5	
	15				17	12.5	
					20	12.5	
					18	14.	
					35	16.	
					40	15.	
	20				-	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-8 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					92	20.	Stopped driving at 22 ft at 5:30 p.m. on 9/23/86 due to erratic BP gage
					105	20.5	
					-	20.5	---------------
4970					53	20.5	Started driving at 8:42 a.m. on 9/25/86 with new BP gage and hose
	25				43	19.5	
					35	19.5	
					35	19.5	
					38	19.	
					38	17.	
	30				24	14.5	
					13	15.	
					17	16.	
					26	14.5	
4960					14	14.5	
	35				11	15.	
					17	15.	
					15	14.	
					14	15.	
					9	15.	
	40				13	14.5	
					14	15.5	
					14	15.	
					14	15.5	
4940					16	16.5	
	45				24	17.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-8 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					31	17.5	
					28	17.	
					24	14.5	
					19	13.	
	50				15	15.5	
					16	16.5	
					19	17.	
					21	17.5	
4940					25	19.	
	55				45	20.5	
					62	21.	
					76	21.	
					80	21.	
					90	21.	
	60				116	21.5	
					143	22.5	
					208	22.5	
					460	23.	
4930					780	22.	
	65				600	23.5	
					350	20.5	
					280	24.	
					184	22.5	
					150	23.	
	70				122	23.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-8 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					180	23.5	
					192	23.5	
					128	23.5	
4920					75	21.5	
	75				45	20.	
					23	18.5	
					17	17.5	
					16	17.	
					14	17.5	
	80				14	18.	
					12	18.	
					13	18.	
					13	17.5	
4910					13	17.	
	85				13	16.5	
					13	16.5	
					13	18.5	
					22	20.	
					90	21.5	
	90				1000+	24.	1000 for 11 in.

Stopped driving at 11:13 a.m. - Casing withdrawn by 11:45 a.m. on 9/25/86

Weather: Clear with high clouds on 9/23/86, cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

Redrive

Depth (ft)	N_B	BP (psig)
87	4/ 6 in.	14.
88	7	16.
89	7	16.
90	100/11 in.	22.

B E C K E R   D R I L L   L O G

Hole No. BOC 86-8
Surf. Elev. 4994 ft.
Max. Depth 104.3 ft.

Project RIRIE DAM SEISMIC STABILITY Date Drilled 9/25-26/86
Feature Foundation Exploration Attitude Vertical
Location Ririe Dam - Downstream Berm Logged by L. F. Harder
Driller Ken Arnold Drill Rig AP-1000 (No. 57) Depth to water ____ ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					15	15.	Started driving at 4:15 p.m. on 9/25/86
					18	14.	
			0 - 8 feet Slightly moist sandy gravel with broken cobble pieces. Most gravel and cobble particles are subangular to angular in shape - small fines content.		17	13.	
4990		GW			45	18.5	
	5				20	15.5	
					44	18.5	
					42	17.5	
			8 - 11 feet Slightly moist sandy gravel with broken cobble pieces. Most gravel and cobble particles are subangular to angular in shape - small fines content. Similiar to 0-8 ft interval.		29	16.5	
		GW			22	15.5	
	10				37	18.5	
					56	18.5	
			11 - 16 feet Poor recovery - just recently broken cobble fragments.		35	17.5	
		GP?			28	15.5	
4980					25	16.	
	15				18	14.5	
			16 - 18 feet Slightly moist sandy gravel with broken cobble pieces. Most gravel and cobble particles are subangular to angular in shape - small fines content.		13	12.5	
		GW		B-1	17	14.5	
					49	18.	
					38	19.	
	20				30	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-8 Page 2/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			18 - 24 feet		34	17.5	
			No recovery		35	18.5	
					30	19.	Stopped driving at 5:30 p.m. on 9/25/86
4970			24 - 28 feet		29	19.5	
	25		Slightly moist sandy gravel with broken cobble fragments. Gravel particles are generally subangular to angular in shape.		30	17.5	Removed entire casing from hole to remove cobbles and sand blocking bit and inner casing.
		GW		B-2	28	17.5	
					29	17.5	
			28 - 32 feet		24	17.	
					25	17.	Started driving at 24 ft at 8:30 a.m. on 9/26/86.
	30	GW	Slightly moist sandy gravel with broken cobble fragments. Gravel particles are generally subangular to angular in shape.		29	18.	
					56	19.5	
					35	18.5	
			32 - 38 feet		29	18.	
4960			Slightly [illegible]ist sandy silt/silty sand wi[illegible]me gravel and cobble partic[illegible]gether with occasional small [illegible]n. wood fibers.		39	19.	
	35	ML-SM		B-3	25	17.	
					23	16.5	
					14	16.	
					16	15.	
			38 - 46 feet		16	15.5	
	40		Wet (saturated?) sandy silty / silty sand. Similiar to 32-38 ft interval but with fewer gravel and cobble particles. Maximum particle size is about 3/4 in. with one wood (root?) fragment approximately 3/4 in. in diameter and about 3 in. long.		11	14.5	
					13	15.	
					12	15.5	
		ML-SM		B-4	13	15.	
4950					15	15.5	
	45				16	16.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-8 Page 3/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		ML-SM		B-4			
					24	16.	
			46 - 52 feet		33	17.5	
			Wet sandy gravel. Maximum particle size about 1-1/2 in. Particle shapes subrounded to angular.		45	19.5	
		GW		B-5	40	18.5	
	50				26	17.	
					21	16.5	
					19	16.5	
			52 - 58 feet		27	16.5	
4940			Wet, sandy gravel. Particle shapes are subrounded to angular. Similiar to 46-52 ft interval but with more sand and with rounded cobble fragments to 4 in.		55	19.	
	55	GW		B-6	65	20.	
					66	19.5	
					65	19.5	
					60	19.5	
			58 - 64 feet		53	19.	
	60		Wet sandy gravel. Similiar to 52-58 ft interval but with lenses of sandy silt/silty sand. Particles are generally subrounded to subangular.		44	18.5	
		GW-GM		B-7	47	18.5	
					68	20.	
					95	21.	
4930					133	22.	
	65		**64 - 70 feet**		140	21.5	
			Wet, sandy gravel with lenses of sandy silt/silty sand. Particles are generally subrounded to subangular. Similiar to 58-64 ft interval.		240	22.	
					200	22.	
		GW-GM		B-8	170	21.5	
					130	22.	
	70				80	22.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-8 Page 4/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GP	<u>70 - 71 feet</u>	B-9			
			Lense of subrounded 1-1/2 in. gravel with some sand.		95	21.5	
			<u>71 - 75 feet</u>		170	22.5	
			Very small recovery.		117	22.	
4920					80	20.	
	75		<u>75 - 78 feet</u>		30	16.5	
		GM-GW	Sandy, silty gravel. Gravel particles are subrounded and range up to 3 inches.	B-10	30	16.	
					15	15.5	
					15	16.5	
			<u>78 - 84 feet</u>		11	16.5	
	80		Wet, sandy, clayey silt with occasional rounded gravel and cobble particles (3-in. max.).		8	16.5	
		MH-GC		B-11	10	16.	
					8	16.	
					25	20.	
4910					22	19.	
	85		<u>84 - 88 feet</u>		14	17.5	
		MH	Wet, sandy, clayey silt with trace of fine (pea) gravel.	B-12	12	17.	
			At 88 ft, free water found in casing after adding new casing segment.		10	17.5	
					11	17.	
					28	19.	
			<u>88 - 98 feet</u>		63	20.	
	90		Sandy clay with broken rounded black basalt gravel and broken cobble particles. Weathered rock?		73	20.5	
		CL-GC		B-13	37	18.	
					29	18.5	
4900					30	19.	
	95				22	17.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-8 Page 5/ 5

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					18	17.5	
		CL-GC		B-13	14	17.5	
					15	17.	
			98 - 104 feet		20	18.	
	100		High water content recovery (soupy mix).		23	18.	
					34	17.5	
		CL-GC	Sandy clay with broken rounded black basalt gravel and cobble particles. Weathered rock?	B-14	36	17.5	
					29	17.5	
4890					52	19.	
	105				1100+	21.5	1100/4 in.

Stopped driving at 11:04 a.m. - Casing withdrawn by 11:45 a.m. on 9/26/86.

Weather: Cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	16 - 18
B - 2	24 - 28
B - 3	32 - 38
B - 4	38 - 46
B - 5	46 - 52
B - 6	52 - 58
B - 7	58 - 64
B - 8	64 - 70
B - 9	70 - 71
B - 10	75 - 78
B - 11	78 - 84
B - 12	84 - 88
B - 13	88 - 98
B - 14	98 - 104

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

BECKER DRILL LOG

Hole No. BCC 86-9
Surf. Elev. 5003 ft.
Max. Depth 69. ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/26/86
Feature Foundation Exploration — Attitude Vertical
Location Ririe Dam - Downstream Berm — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 12:35 p.m. on 9/26/86
5000					15	14.	
					20	14.5	
	5				20	14.	
					26	15.5	
					25	16.5	
					28	17.	
					35	18.	
	10				34	19.	
					58	19.	
					84	19.5	
4990					62	21.	
					57	20.	
	15				38	18.5	
					41	18.	
					29	16.5	
					33	17.	
					38	18.5	
	20				32	18.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-9 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					23	17.5	
					26	17.	
4980					56	20.	
					148	23.	
	25				115	22.5	
					94	21.	
					95	20.5	
					100	20.5	
					81	21.	
	30				113	21.5	
					178	23.	
					178	23.	
4970					110	21.	
					105	21.	
	35				108	21.	
					130	21.	
					112	21.	
					76	20.	
					56	19.5	
	40				66	20.5	
					57	20.	
					69	20.	
4960					59	20.	
					63	20.	
	45				79	20.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-9 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					88	21.	
					104	21.5	
					139	21.5	
					-	20.5	
	50				43	19.5	
					32	19.	
					39	19.5	
4950					39	20.	
					48	20.	
	55				54	21.	
					59	21.	
					54	21.	
					62	21.	
					63	21.5	
	60				55	21.	
					49	20.5	
					29	20.	
4940					39	21.5	
					118	22.5	
	65				294	24.5	
					235	23.5	
					232	24.	
					102	23.	
	69				102	24.	

Stopped driving at 3:00 p.m. - Casing withdrawn by 3:25 p.m. on 9/26/86

Weather: Cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

B E C K E R   D R I L L   L O G

Hole No. BOC 86-9
Surf. Elev. 5003 ft.
Max. Depth 68. ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/27/86
Feature Foundation Exploration — Attitude Vertical
Location Ririe Dam - Downstream Berm — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ____ ft.

6-5/8 " O.D. Open 8-tooth Crowd-out Bit - Sampling with reverse air circulation

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
			<u>0 - 8 feet</u>		7	14.	Started driving at 12:10 p.m. on 9/27/86
5000			Moist, silty, sandy gravel and cobble fragments. Gravel and cobble fragments are generally subangular.		19	13.	
		GW-GM			13	12.	
	5				13	16.	
					21	17.	
					21	16.	
					33	17.	
			<u>8 - 16 feet</u>		38	19.5	
	10		Moist, silty, sandy gravel and cobble fragments. Gravel and cobble fragments are generally subangular with numerous freshly broken angular gravel-sized shavings that have been cut by the bit from larger cobbles.		25	17.5	
					23	16.	
		GW-GM		B-1	36	18.5	
4990					27	18.	
					30	18.5	
	15				24	17.	
			<u>16 - 28 feet</u>		25	17.	
			Moist, silty, sandy gravel and cobble fragments. Gravel and cobble fragments are generally subangular together with numerous freshly broken angular gravel-sized shavings and with several 4-in. broken basalt particles.		32	18.	
		GW-GM			40	18.5	
					35	19.	
	20				35	19.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-9 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					50	20.5	
					40	18.5	
4980					37	18.	
		GW-GM			60	20.	
	25				58	20.5	Stopped driving at 12:40 p.m. because of fracture which developed in drive frame
					53	20.	
					60	20.	
					70	21.5	------------
					45	20.5	Resumed driving at 1:30 p.m on on 9/27/86 after replacing with spare drive frame
	30		<u>30 - 37 feet</u>		25	18.5	
			Moist, silty, sandy gravel and broken cobble fragments. Gravel and cobble particles are subangular to angular and many appear to have been freshly broken by the bit from larger particles.		35	19.5	
					45	18.5	
4970					29	18.	
		GW-GM		B-2	45	19.	
	35				56	20.5	
					70	20.5	
					40	19.	
					32	18.	
			<u>38 - 44 feet</u>		40	19.	
	40		Moist, sandy gravel and broken cobble fragments. Small fines content. Gravel and cobble fragments are subangular to angular and many appear to have been freshly broken from larger particles.		39	18.	
		GW			43	18.	
				B-3	42	17.5	
4960					33	19.5	
					42	14.	
	45	GW			60	17.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-9 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
		GW	<u>44 - 49 feet</u> Moist, sandy gravel with cobble fragments. Small fines content. Gravel and cobble particles are generally subangular to angular and many indicate freshly broken surfaces.		58 83 63	19.5 20.5 20.5	
	50	GW-GM	<u>49 - 50 feet</u> gradational change with silt, sand, and both subangular and subrounded gravel particles.		56 43	20. 19.	
4950		GW-GM	<u>50 - 55 feet</u> Silty, sandy gravel. Gravel particles are subrounded with maximum particle size about 2 inches.	B-4	22 17 27 20	17. 18.5 17. 15.	
	55	ML	<u>55 - 58 feet</u> Sandy silt with occasional gravel particles and small bits of wood or roots. Very moist to saturated.	B-5	15 10 13	16. 16. 16.5	
	60	ML	<u>58 - 62 feet</u> Sandy silt with occasional gravel particles and small bits of wood or roots. Very moist to saturated. Similiar to 55-58 ft interval.	B-6	15 19 21 40	15.5 17.5 19. 17.5	
4940	65	ML, GC, CL	<u>62 - 66 feet</u> Gradational change between sandy silt to gravelly, sandy silt to sandy clayey rounded gravel to sandy, silty clay with basalt fragments.		15 10 12 16	16.5 16.5 18.5 18.5	
	68	GC bedrock?	<u>66 - 68 feet</u> Sandy, silty, clayey gravel with broken subangular to angular black basalt particles and basalt shavings. (Weathered bedrock?)	B-7	20 45 230	18. 21. 22.5	

Stopped driving at 2:25 p.m. - Casing withdrawn by 3:45 p.m. on 9/27/86.

Project RIRIE DAM SEISMIC STABILITY Hole No. BOC 86-9 Page 4/ 4

Weather: Cloudy with occasional showers. Temperature range about 40 - 60 degrees F.

Samples:

Sample I.D.	Depth Interval (feet)
B - 1	8 - 16
B - 2	30 - 37
B - 3	40 - 44
B - 4	50 - 55
B - 5	55 - 58
B - 6	58 - 62
B - 7	66 - 68

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

Appendix B: Corrected Bounce Pressure Versus Becker Blowcount Data Measured at Jackson Lake Dam

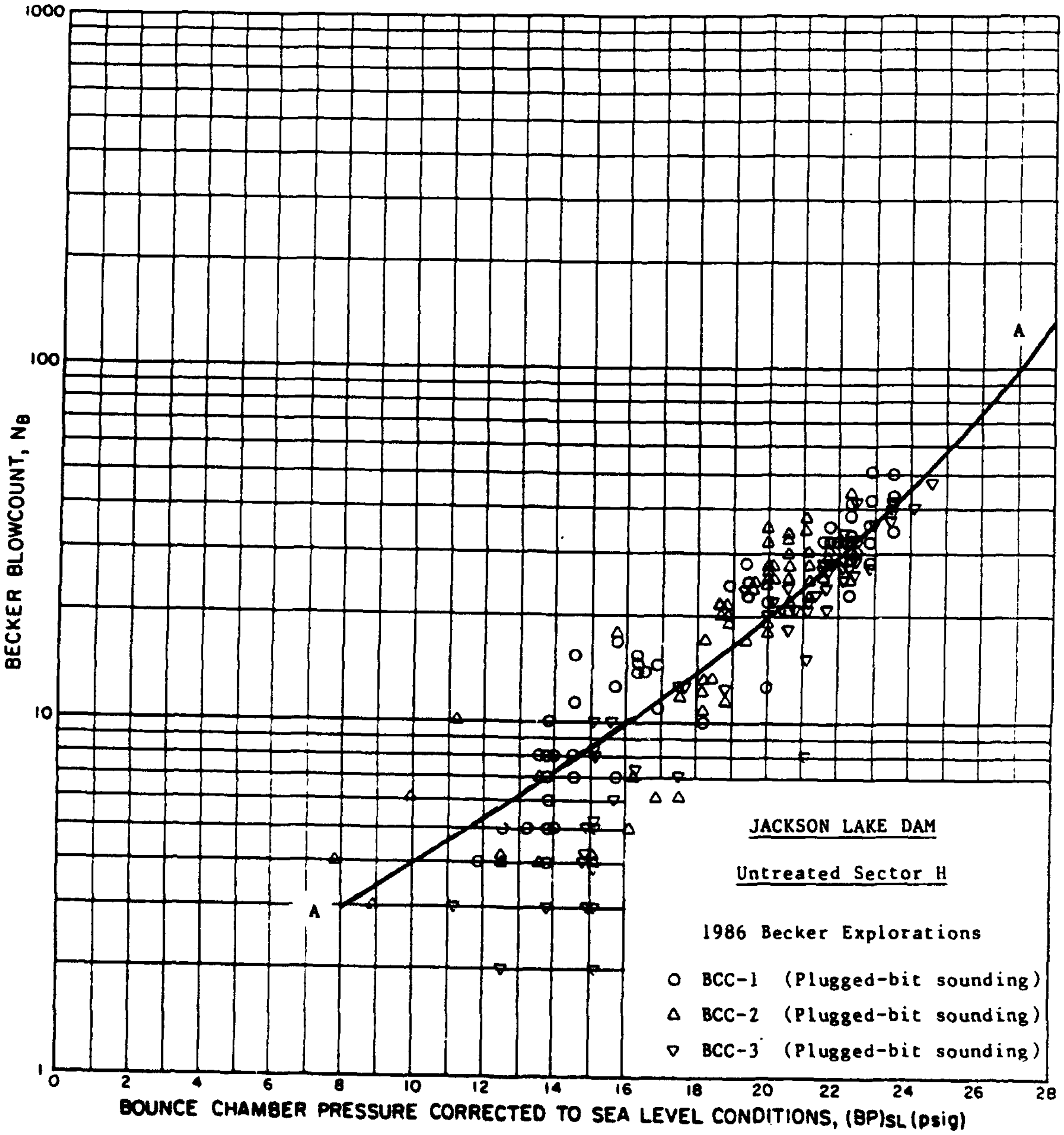

Figure B1. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Jackson Lake Dam section H

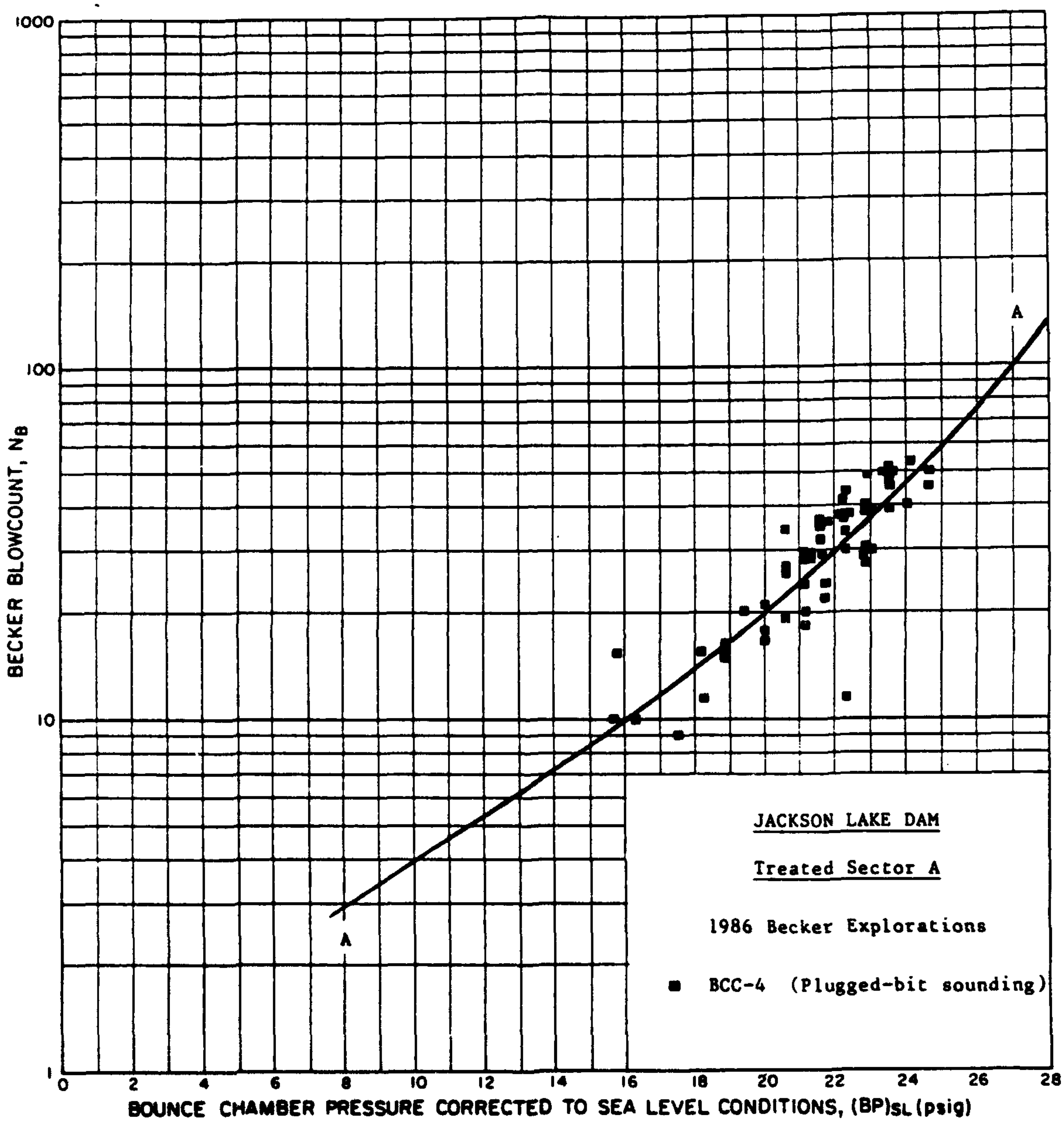

Figure B2. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Jackson Lake Dam Sector A

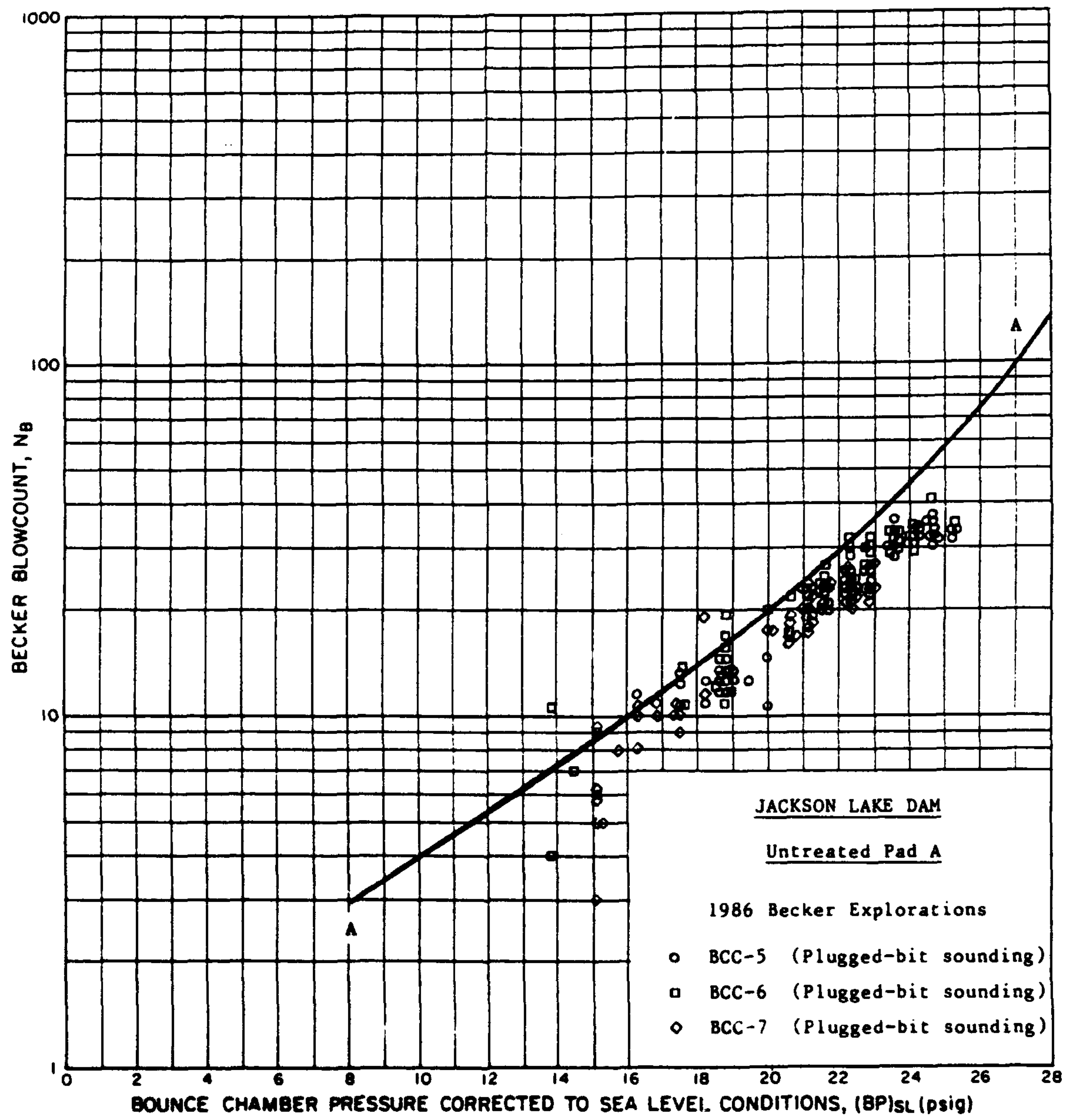

Figure B3. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Jackson Lake Dam Pad A

Appendix C: Calculation Tables for Determining Equivalent SPT blowcounts from Becker data obtained at Jackson Lake Dam

JACKSON LAKE DAM

DEPTH (feet)	BCC-1					BCC-2					BCC-3				
	N_R	BP	BP_c	N_{RC}	N_{60}	N_R	BP	BP_c	N_{RC}	N_{60}	N_R	BP	BP_c	N_{RC}	N_{60}
1	13														
2	17					12	12	17.5	12½	12½ [9½]	13	12	17.5	13	13 [10]
3						19	14	20.0	19½	18½ [14]	18	14½	20.6	19½	18½ [14]
4	28	13½	19.4	24	22 [14½]	25	16	22.3	26	23 [17½]	22	14	20.0	21	20 [15]
5	26	13½	19.4	23	21½ [16]	26	15½	21.7	26	23½ [17½]	27	15	21.1	26	23½ [17½]
6	24	13	18.8	20½	19½ [19½]	25	15	21.1	24½	22½ [17]	29	16	22.3	30	26 [19½]
7	17	10½	15.7	13	13 [10]	22	14½	20.6	22	20½ [15½]	20	14	20.0	20	19 [14½]
8	16	9½	14.5	11	11	19	13	[illegible]	18	17½	13	12	17.5	13	13
9	13	10½	15.7	11	11	17	12½	[illegible]	16	16	10	10½	15.7	9½	9½
10	12	9½	14.5	9	9	14	12½	[illegible]	14	14	5	10	15.1	6½	6½
11	9	9½	14.5	8	8	14	12½	18.2	14	14	4	11½	16.9	6½	6½
12	4	7½	11.9	4½	4½	18	14	[illegible]	18½	18	7	12	17.5	9½	9½
13	7	9½	14.5	7½	7½	20	13	[illegible]	18½	18	13	13	18.8	14	14
14	14	11	16.3	13	13	18	10½	15.7	13½	13½	8	10	15.1	8½	8½
15	16	11	16.3	14	14	10	7	11.2	6½	6½	4	10	15.1	6	6
16	15	11	16.3	13½	13½	6	6	[illegible]	5	5	3	9	13.8	5½	5½
17	10	9	13.8	8	8	3	5	[illegible]	3½	3½	2	8	12.5	4	4
18	5	8	12.5	5½	5½	4	4	7.3	3½	3½	3	7	11.2	4	4
19	5	8½	13.2	5½	5½	4	9	13.8	5½	5½	2	10	15.1	5	5
20	9	9	13.8	7½	7½	4	8	[illegible]	5	5	3	10	15.1	5½	5½
21	7	9	13.8	7	7	4	10	15.1	6	6	4	10	15.1	6	6
22	5	9	13.8	6	6	5	11	16.3	7	7	10	10	[illegible]	9	9
23	6	9	13.8	6½	6½	7	9	[illegible]	7	7	5	10	15.1	6½	6½
24	4	9	13.8	5½	5½	4	8	12.5	5	5	3	10	15.1	5½	5½
25	5	9	13.8	6	6	4	10	15.1	6	6	4	10	[illegible]	6	6
26	9	9	[illegible]	7½	7½	7	11	[illegible]	8½	8½	5	10	15.1	6½	6½
27	9	9	[illegible]	7½	7½	6	11½	16.9	8	8	8	10	15.1	8	8
28	7	10½	15.7	8	8	6	12	17.5	8½	8½	6	10½	15.7	7½	7½
29	14	11	16.3	13	13	13	12½	13.2	13½	13½	7	11	16.3	8½	8½
30	11	11½	16.9	11	11	11	12½	13.2	12	12	8	15	21.1	11½	11½
31	10	12½	18.2	12	12	12	13	18.8	13	13	15	15	21.1	18	17½
32	15	11½	16.9	14	14	17	13½	19.4	17½	17	22	15	21.1	22½	21
33	13	14	20.0	15	15	23	15	21.1	23½	22	21	15½	21.7	22½	21
34	21	14½	20.6	21	20	27	14½	20.6	25½	23	21	15	21.1	22	20½
35	23	13½	19.4	21	20	27	14	20.0	24½	22½	21	14½	20.6	21½	20
36	22	14	20.0	21	20	28	14	20.0	25	23	24	14½	20.6	23	21½
37	23	16	22.3	25	23	26	14	20.0	24	22	21	14½	20.6	21½	20
38	30	16	22.3	30	26	25	14	20.0	23½	22	23	13½	19.4	21	20
39	30	16	22.3	30	26	26	14	20.0	24	22	26	16	22.3	27	24½
40	38	16½	22.9	37	31	29	15½	[illegible]	28½	25	28	16½	22.9	29½	25½

JACKSON LAKE DAM

DEPTH (feet)	BCC-1 N_c	BCC-1 BP	BCC-1 BP_c	BCC-1 N_{BC}	BCC-1 N_{60}	BCC-2 N_B	BCC-2 BP	BCC-2 BP_c	BCC-2 N_{BC}	BCC-2 N_{60}	BCC-3 N_B	BCC-3 BP	BCC-3 BP_c	BCC-3 N_{BC}	BCC-3 N_{60}		DEPTH (feet)
41	41	16	22.3	39	32½	31	15½	21.7	30½	26½	29	15½	21.7	29	25½		41
42	43	17	23.5	42	34½	28	15	21.1	27	24½	29	16	22.3	29½	25½		2
43	50	17	23.5	49	39	30	15	21.1	29	25½	27	15½	21.7	27	24½		3
44	51	16½	22.9	49	39	34	14½	20.6	33	28	22	15	21.1	22½	21		4
45	42	16½	22.9	41	33½	28	14	20.0	25	23	27	16	22.3	28	25		5
46	36	15½	21.7	34	29	22	13	18.8	19½	18½	40	17	23.5	40	33		6
47	34	17	23.5	35	29½	20	13	18.8	18½	18	41	17	23.5	41	33½		7
48	38	16	22.3	37	31	22	13	18.8	19½	18½	33	16	22.3	32½	28		8
49	32	16½	22.9	33	28	26	14½	20.6	25	23	29	16	22.3	30	26		9
50	34	16	22.3	33	28	33	14½	20.6	30	26	24	15½	21.7	25	23		50
51	32	15½	21.7	31	27	30	14½	20.6	28	25	25	16	22.3	26½	24		11
52	28	15½	21.7	28	25	25	13½	19.4	23	21½	33	16	22.3	32½	28		12
53	32	15½	21.7	31	27	24	13½	19.4	22	20½	46	16½	22.9	44	36		13
54	32	15½	21.7	31	27	32	14	20.0	28	25	47	18	24.6	47½	38		14
55	32	16	22.3	32	27½	36	14	20.0	31	27	40	17½	24.1	41	33½		15
56	32	16	22.3	32	27½	38	15	21.1	35	29½	39	17	23.5	39	32½		16
57	36	16½	22.9	36	30½	35	15	21.1	32	27½	37	17	23.5	38	31½		
58	29	16	22.3	30	26	44	16	22.3	41	33½	42	16	22.3	40	30		18
59																	19
60																	60
61																	21
62																	22
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78																	38
79																	39
80																	80

JACKSON LAKE DAM

BCC-4					
DEPTH (feet)	N_B	BP	BP_C	N_{RC}	N_{60}
1					
2	16	12½	18.2	15	15 11½
3	16	10½	15.7	12	12 9
4	17	14	20.0	18	17½ 13
5	18	14	20.0	18½	18 13¾
6	16	13	18.9	16	16 12
7	16	13	18.8	16	16 12
8	15	13	15.3	15½	15½
9	10	10½	15.7	9½	9½
10	10	11	16.3	10½	10½
11	24	15½	21.7	25	23
12	24	15	21.1	24	22
13	31	16½	22.9	32	27½
14	40	17½	24.1	41	33½
15	45	18	24.6	46	37
16	50	18	24.6	50	40
17	53	17½	24.1	52	41
18	51	17	23.5	49	39
19	47	17	23.5	46	37
20	46	17	23.5	45	36½
21	41	16	22.3	39	32½
22	36	15½	21.7	33½	28½
23	35	15½	21.7	33	28
24	36	15½	21.7	33½	28½
25	37	16	22.3	36	30½
26	38	16½	22.9	38	31½
27	34	14½	20.6	30½	26½
28	20	13½	19.4	19	18½
29	12	12½	18.2	13	13
30	9	12	17.5	10½	10½
31	12	16	22.3	15½	15½
32	39	17	23.5	39½	32½
33	50	17	23.5	48	38½
34	49	16½	22.9	46	37
35	44	16	22.3	41	33½
36	37	16	22.3	36	30½
37	40	16½	22.9	39½	32½
38	50	17	23.5	48	38½
39	38	16½	22.9	38	31½
40	38	16	22.3	37	31

JACKSON LAKE DAM

DEPTH (feet)	BCC-4 N_R	BP	BP_C	N_{RC}	N_{60}
41	28	15½	21.1	27	24½
42	27	14½	20.6	25	23
43	29	15	21.1	28	25
44	28	15	21.1	27	24½
45	29	15	21.1	28	25
46	26	14½	20.6	25	23
47	21	14	20.0	20½	19½
48	19	14½	20.6	20	19
49	20	15	21.1	22	20½
50	18	15	21	20	19
51	23	15½	21.7	24	22
52	27	16½	22.9	29	25½
53	28	16½	22.9	29½	25½
54	30	16½	22.9	31½	27½
55	34	16	22.3	33½	28½
56	32	15½	21.7	31	27
57	29	15½	21.7	29	25½
58	30	16	22.3	30½	26½
59					
60					
61					
62					
63					
64					
65					
66					
67					
68					
69					
70					
71					
72					
73					
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75					
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77					
78					
79					
80					

JACKSON LAKE DAM

DEPTH (feet)	BCK-5					BCC-6					BCC-7				
	N_R	BP	BP_c	N_{RC}	N_{60}	N_R	BP	BP_c	N_{RC}	N_{60}	N_R	BP	BP_c	N_{RC}	N_{60}
1															
2	9	10	15.1	8½	8½	7	9½	14.5	7½	7½	6	10	15.1	7	7
3	12	11½	16.3	11½	11½	6	10	15.1	7	7	6	10	15.1	7	7
4	14	12	17.5	13½	13½	4	9	13.8	5½	5½	8	11	16.3	9	9
5	15	13	18.8	15½	15½	11	9	13.8	8½	8½	10	11½	16.9	10½	10½
6	13	13½	19.4	14½	14½	15	13	18.8	15½	15½	11	12	17.5	11½	11½
7	13	12	17.5	13	13	17	13	18.8	16½	16½	10	12	17.5	11	11
8	14	13	18.8	14½	14½	14	12	17.5	13½	13½	8	10½	15.7	8½	8½
9	12	13	18.8	13½	13½	13	13	18.8	14	14	5	10	15.1	6½	6½
10	13	13	18.8	14	14	11	13	18.8	12½	12½	11	11	16.3	10½	10½
11	11	14	20.0	13½	13½	11	12	17.5	11½	11½	11	11½	16.9	11	11
12	11	12	17.5	11½	11½	12	13	18.8	13½	13½	9	10	15.1	8½	8½
13	14	13	18.8	14½	14½	17	14½	20.6	18½	18	5	10	15.1	6½	6½
14	12	13	18.8	13½	13½	23	15½	21.7	24	22	3	10	15.1	5½	5½
15	13	12½	18.2	13½	13½	20	14	20.0	20	19	9	12	17.5	10½	10½
16	11	12½	18.2	12	12	19	13	18.8	18	17½	10	11	16.3	10	10
17	13	12½	18.2	13½	13½	16	13	18.8	16	16	10	12	17.5	11	11
18	14	13	18.8	14½	14½	22	14½	20.6	22	20½	12	12½	18.2	13	13
19	14	13	18.8	14½	14½	—	15	21.1	—	—	14	13	18.8	14½	14½
20	13	13	18.8	14	14	25	16	22.3	26½	24	18	15	21.1	20	19
21	13	13	18.8	14	14	27	15½	21.7	27	24½	20	15	21.1	21½	20
22	15	14	20.0	16½	16½	19	15	21.1	20½	19½	22	15	21.1	23	21½
23	19	15	21.1	20½	19½	23	15	21.1	23½	22	21	15	21.1	22	20½
24	23	15	21.1	23½	22	25	15½	21.7	26	23½	23	15	21.1	23½	22
25	23	15½	21.7	24	22	24	15½	21.7	25	23	26	16½	22.9	28	25
26	24	16	22.3	26	23½	24	15½	21.7	25	23	25	16	22.3	26½	24
27	23	16	22.3	25	23	24	15½	21.7	25	23	22	15	21.1	23	21½
28	26	16	22.3	27	24½	28	16	22.3	29	25½	19	14½	20.6	20	19
29	21	15½	21.7	23	21½	30	17	23.5	32	27½	17	14	20.0	18	17½
30	20	15½	21.7	22	20½	35	18½	25.2	39	32½	17	14	20.0	18	17½
31	24	16½	22.9	26½	24	41	18	24.6	42½	35	20	16	22.3	23	21½
32	32	17½	24.1	35	29½	33	17	23.5	35	29½	20	15	21.1	21½	20
33	33	17	23.5	35	29½	30	16	22.3	30½	26½	18	14½	20.6	19½	18½
34	27	16½	22.9	29	25½	26	16	22.3	27	24½	18	15	21.1	20	19
35	24	16	22.3	26	23½	29	16½	22.9	30½	26½	17	15	21.1	19	18½
36	23	16	22.3	25	23	27	16½	22.9	29	25½	17	14½	20.6	18½	18
37	27	16½	22.9	29	25½	30	16½	22.9	31	27	16	14½	20.6	17	16½
38	30	17	23.5	32	27½	32	16	22.3	32	27½	17	14½	20.6	18½	18
39	27	16½	22.9	29	25½	29	17½	24.1	32	27½	19	12½	19.2	17	16½
40	28	17	23.5	30½	26½	29	17	23.5	31½	27½	21	15½	21.7	23	21½

JACKSON LAKE DAM

DEPTH (feet)	BCC-5					BCC-6					BCC-7				
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}
41	30	17	23.5	32	27½	31	17	23.5	33	28	21	16	22.3	23½	22
42	31	17½	24.1	33½	28½	33	17	23.5	35	29½	21	16	22.3	23½	22
43	32	17½	24.1	35	29½	32	17½	24.1	35	29½	20	15½	21.7	22	20½
44	32	18	24.6	35	29½	32	16½	22.9	33	28	23	15	21.1	23½	22
45	35	18	24.6	36	30½	32	17½	24.1	35	29½	23	16	22.3	25	23
46	32	18	24.6	35	29½	34	17½	24.1	36½	30½	24	15½	21.7	25	23
47	33	17½	24.1	35½	30	31	16½	22.9	32	27½	23	16	22.3	25	23
48	36	17	23.5	37	31	33	17½	24.1	35½	30	22	15½	21.7	23½	22
49	32	17	23.5	33½	28½						23	16½	22.9	25½	23
50	30	18	24.6	33½	28½						22	16½	22.9	24½	22½
51	35	18	24.6	38	31½						23	16½	22.9	25½	23
52	35	18	24.6	38	31½						23	16½	22.9	25½	23
53	33	18½	25.2	37	31						23	16	22.3	25	23
54	34	17½	24.1	36½	30½						22	16	22.3	24	22
55	34	18½	25.2	38	31½						21	16½	22.9	24	22
56	32	18	24.6	35	29½						23	16	22.3	25	23
57	32	18½	25.2	36	30½						23	15½	21.7	24	22
58	37	18	24.6	40	33						22	16	22.3	24	22
59															
60															
61															
62															
63															
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80															

Appendix D: Borehole logs for 1986 Becker Soundings Performed at Ririe Dam

BECKER DRILL LOG

Hole No. BCC 86-1
Surf. Elev. 4970 ft.
Max. Depth 71 ft.

Project RIRIE DAM SEISMIC STABILITY   Date Drilled 9/17/86
Feature Foundation Exploration   Attitude Vertical
Location Ririe Dam - Downstream Flat Area   Logged by L. F. Harder
Driller Ken Arnold   Drill Rig AP-1000 (No. 57)   Depth to water ft.

6-5/8" O.D. Plugged 8-tooth crowd-out bit - no samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 10:00 a.m. on 9/17/86
					11	15.	
					10	11.5	
					12	13.	
	5				8	12.5	
					9	12.	
					15	13.5	
					19	16.5	
					17	16.5	
4960	10				11	15.	
					22	18.	
					12	15.	
					11	14.	
					11	13.	
	15				9	23.	
					43	19.5	
					22	18.	
					68	22.5	
					381	22.5	
4950	20				415	22.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-1 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					183	22.	
					101	23.	
					37	19.	
					25	17.5	
	25				20	17.5	
					29	19.5	
					35	20.	
					45	21.	
					33	21.	
4940	30				33	21.	
					36	20.5	
					34	19.5	
					34	20.	
					44	21.	
	35				56	23.5	
					70	25.	
					114	24.5	
					146	24.5	
					129	24.5	
4930	40				127	23.5	
					117	24.	
					109	23.5	
					86	23.	
					62	23.	
	45				58	22.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-1 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					45	22.5	
					79	24.	
					142	24.5	
					120	23.5	
4920	50				84	22.	
					63	21.5	
					44	21.	
					29	21.	
					31	21.	
	55				78	22.5	
					92	23.	
					64	21.5	
					56	22.	
					45	21.5	
4910	60				39	21.	
					38	21.	
					43	21.5	
					67	21.5	
					62	21.	
	65				114	22.	*
							* At 68 ft,
					192	22.	* pulled casing
							* up 4 ft
					230	22.5	* and redrove
							*
					426	22.5	*
							*
					774	22.	**At 71 ft,
							**pulled casing
4900	70				1440	22.	**up 3 ft and

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-1 Page 4/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
	71				1570	21.	**redrove 3 ft. ** **

Stopped driving by 1:10 p.m. on 9/15/86. Upon removing casing, found that casing had broken approximately 21 feet down, just past the joint. Believe that casing broke during the hard driving between 68 and 71 feet after the first redriving interval, but before the second redriving interval. Drillers left approximately 49 feet of casing in hole and backfilled upper portion of hole by shovelling cobbles and dirt into hole up to surface.

Weather: Partly cloudy with slight breeze. Temperature range about 38 - 65 degrees F.

Samples: No samples recovered.

Redrive Interval No. 1:

Depth (ft)	N_B	BP (psig)
65	8	15.
66	8	15.
67	19	19.5
68	119	21.

Redrive Interval No. 2:

Depth (ft)	N_B	BP (psig)
69	4	5.
70	6	5.
71	4	10.

BECKER DRILL LOG

Hole No. BCC 86-2
Surf. Elev. 4972 ft.
Max. Depth 71 ft.

Project RIRIE DAM SEISMIC STABILITY — Date Drilled 9/17/86
Feature Foundation Exploration — Attitude Vertical
Location Ririe Dam - Downstream Flat Area — Logged by L. F. Harder
Driller Ken Arnold — Drill Rig AP-1000 (No. 57) — Depth to water ft.

6-5/8 " O.D. Plugged 8-tooth Crowd-out Bit - No samples

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
							Started driving at 2:27 p.m. on 9/17/86
4970					29	23.	
					50	21.	
					21	16.	
	5				9	13.5	
					7	13.	
					10	17.5	
					23	17.5	
					22	19.	
	10				32	19.	
					22	17.	
4960					20	16.5	
					16	16.5	
					21	17.	
	15				25	16.	
					17	15.	
					12	14.5	
					12	14.	
					11	14.5	
	20				11	14.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-2 Page 2/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					10	14.	
4950					10	14.	
					10	13.5	
					9	13.	
	25				7	13.	
					7	13.	
					8	13.	
					13	14.5	
					12	15.	
	30				17	17.	
					29	18.5	
4940					18	17.	
					10	15.	
					9	14.	
	35				8	14.	
					9	14.	
					9	14.5	
					10	14.5	
					9	15.	
	40				8	15.	
					8	14.5	
4930					9	15.5	
					10	15.5	
					35	20.	
	45				39	20.	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-2 Page 3/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
					40	20.5	
					34	20.5	
					19	17.	
					20	17.5	
	50				40	20.	
					30	19.	
4920					19	18.5	
					43	20.5	
					53	20.5	
	55				24	18.5	
					20	18.	
					30	19.5	
					37	20.5	
					29	19.5	
	60				64	21.5	
					93	22.5	
4910					123	23.	
					96	22.5	
					71	21.	
	65				60	21.5	
					96	21.5	
					89	22.5	
					67	22.5	
					197	23.5	
	70				110	23.5	

Project RIRIE DAM SEISMIC STABILITY Hole No. BCC 86-2 Page 4/ 4

Elev (ft)	Depth (ft)	Log	Field Classification and Description	Sample No.	N_B	BP (psig)	Remarks
	71				275	24.5	Stopped driving at 3:40 p.m. on 9/17/86

Weather: Partly cloudy with slight breeze. Temperature range about 55 - 65 degrees F.

Samples: No samples recovered.

Hole backfilled by shovelling cobbles and soil into upper portion of hole up to the surface.

Appendix E: Corrected Bounce Pressure Versus Becker Blowcount Data Measured at Ririe Dam

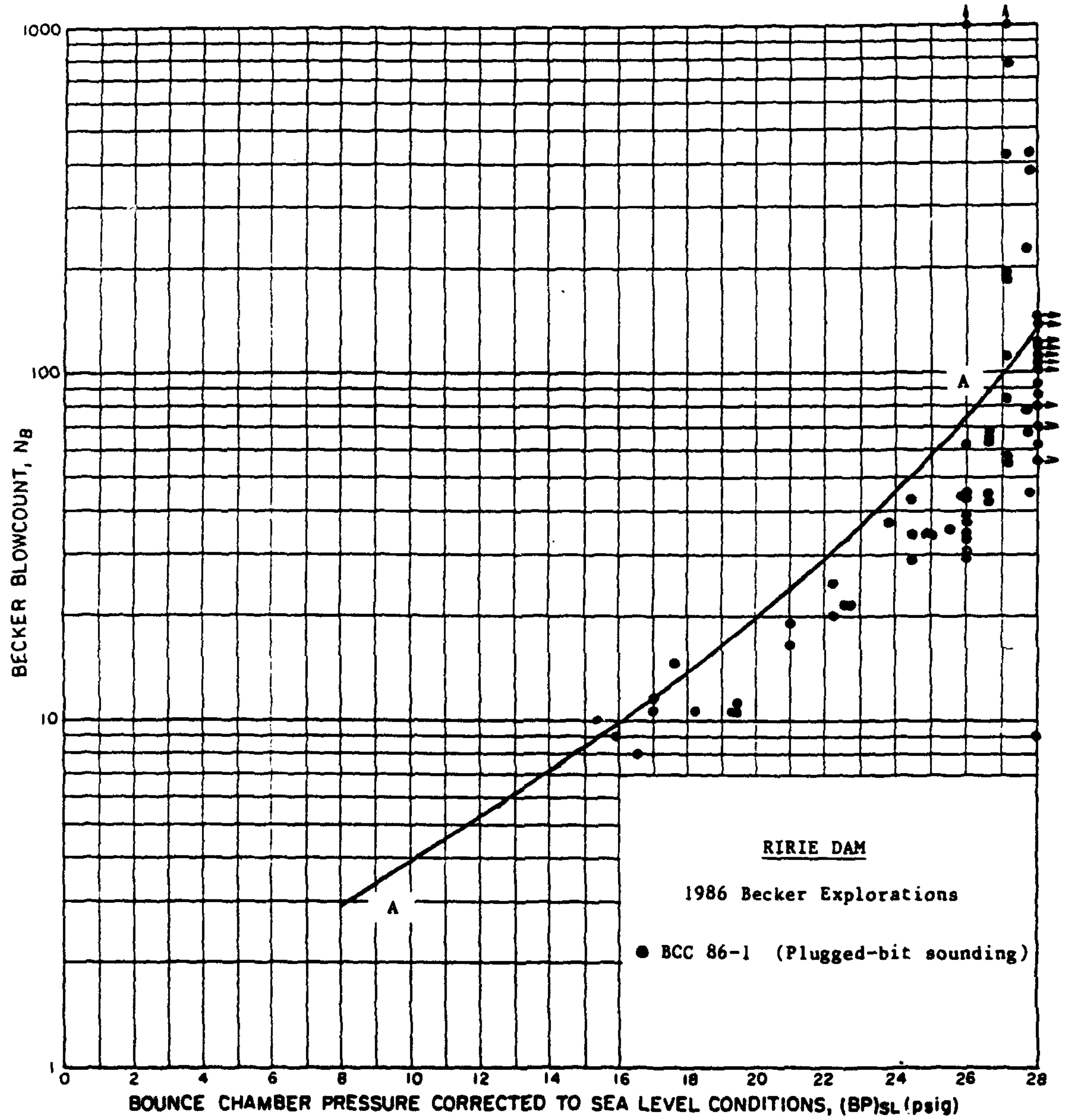

Figure E1. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 1

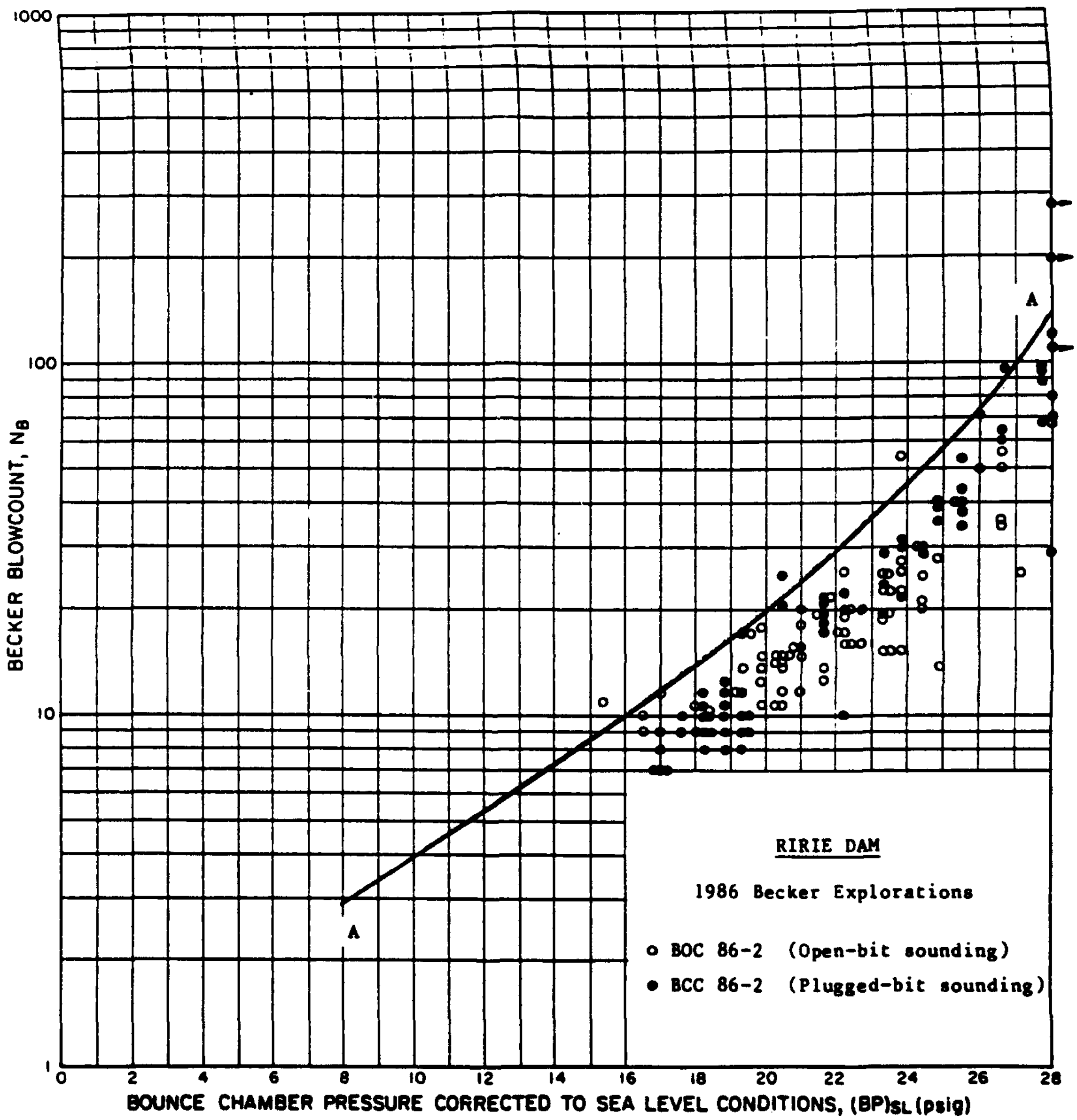

Figure E2. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 2

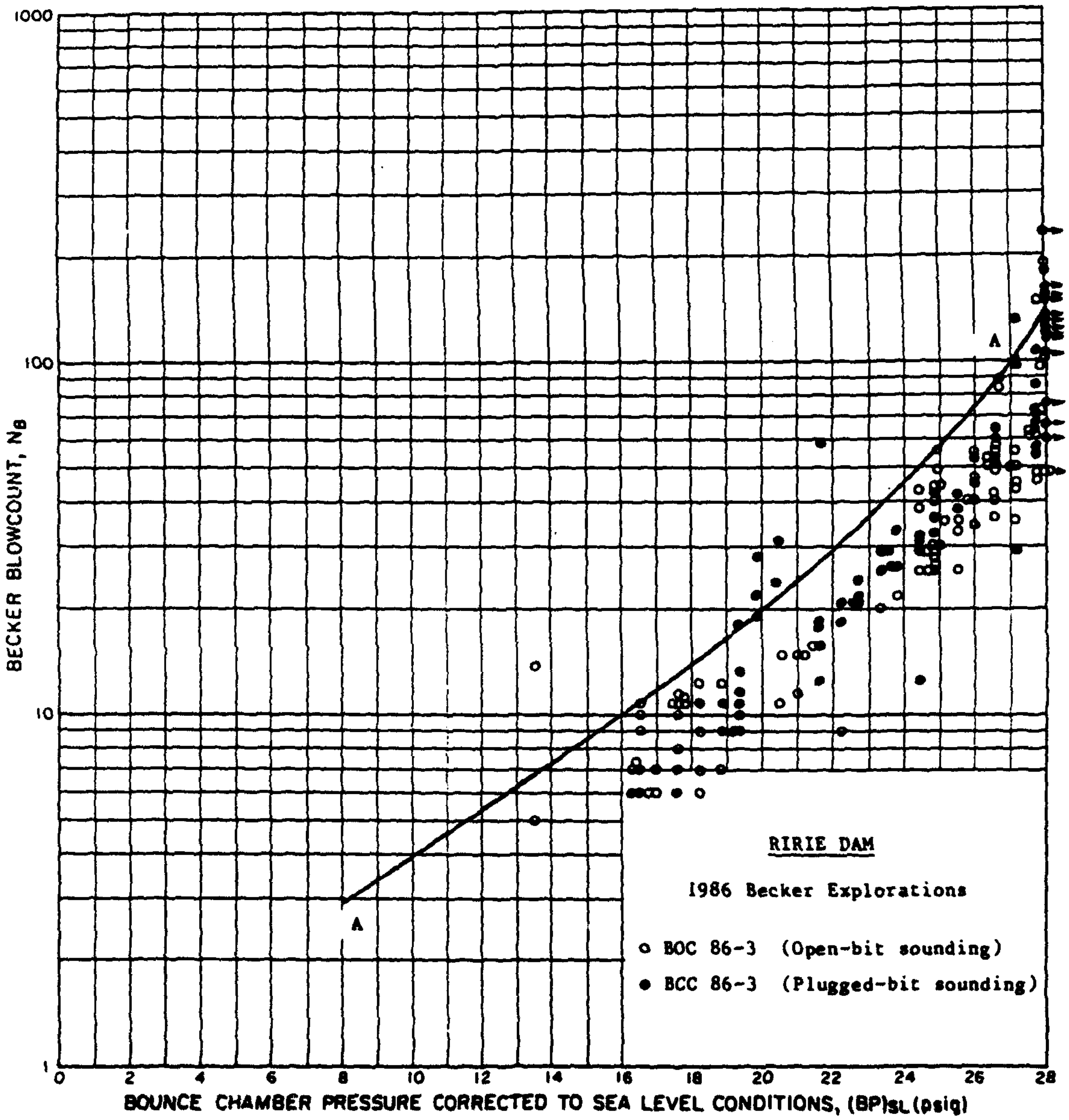

Figure E3. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 3

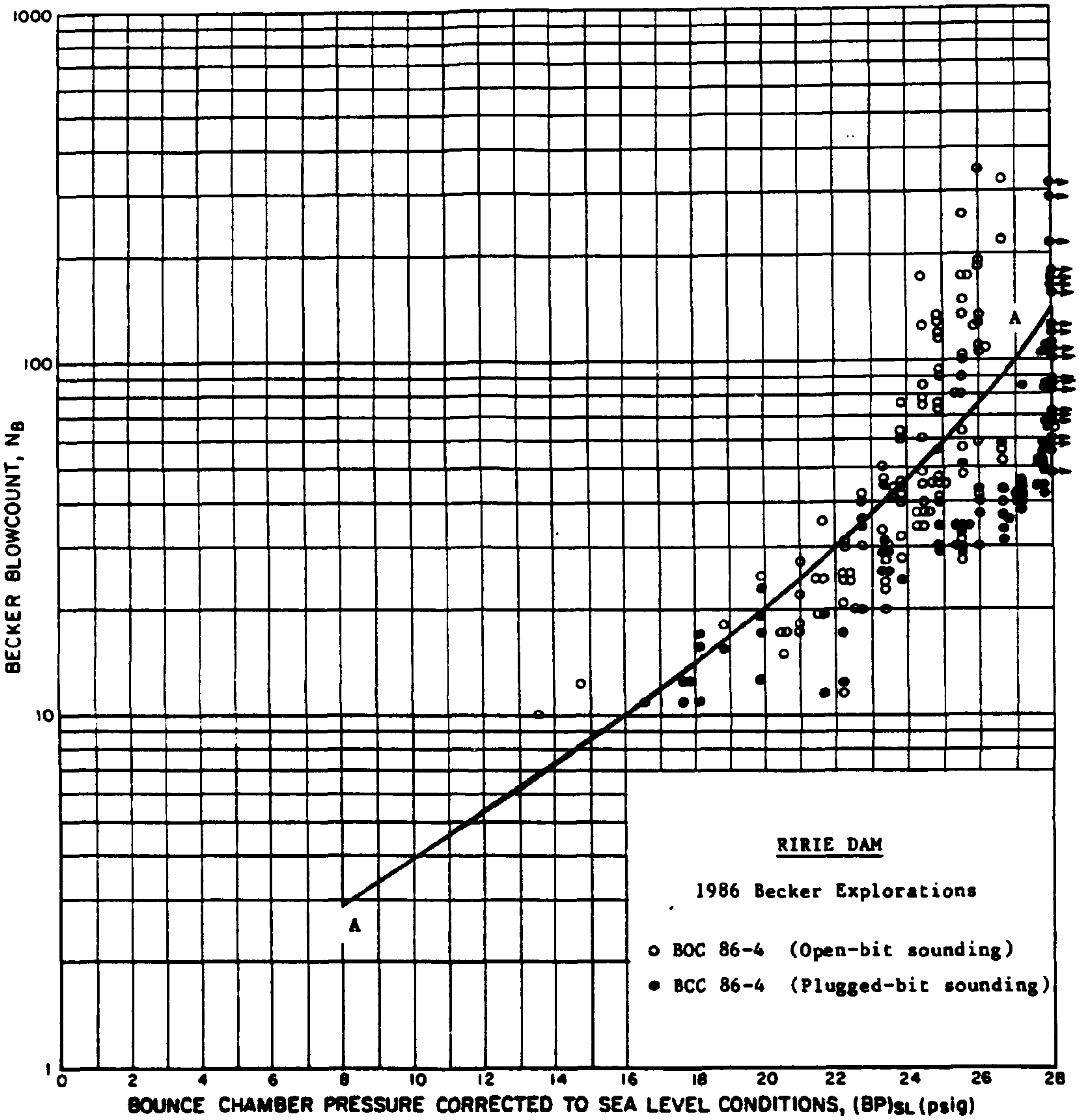

Figure E4. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam-- Drilling Site 4

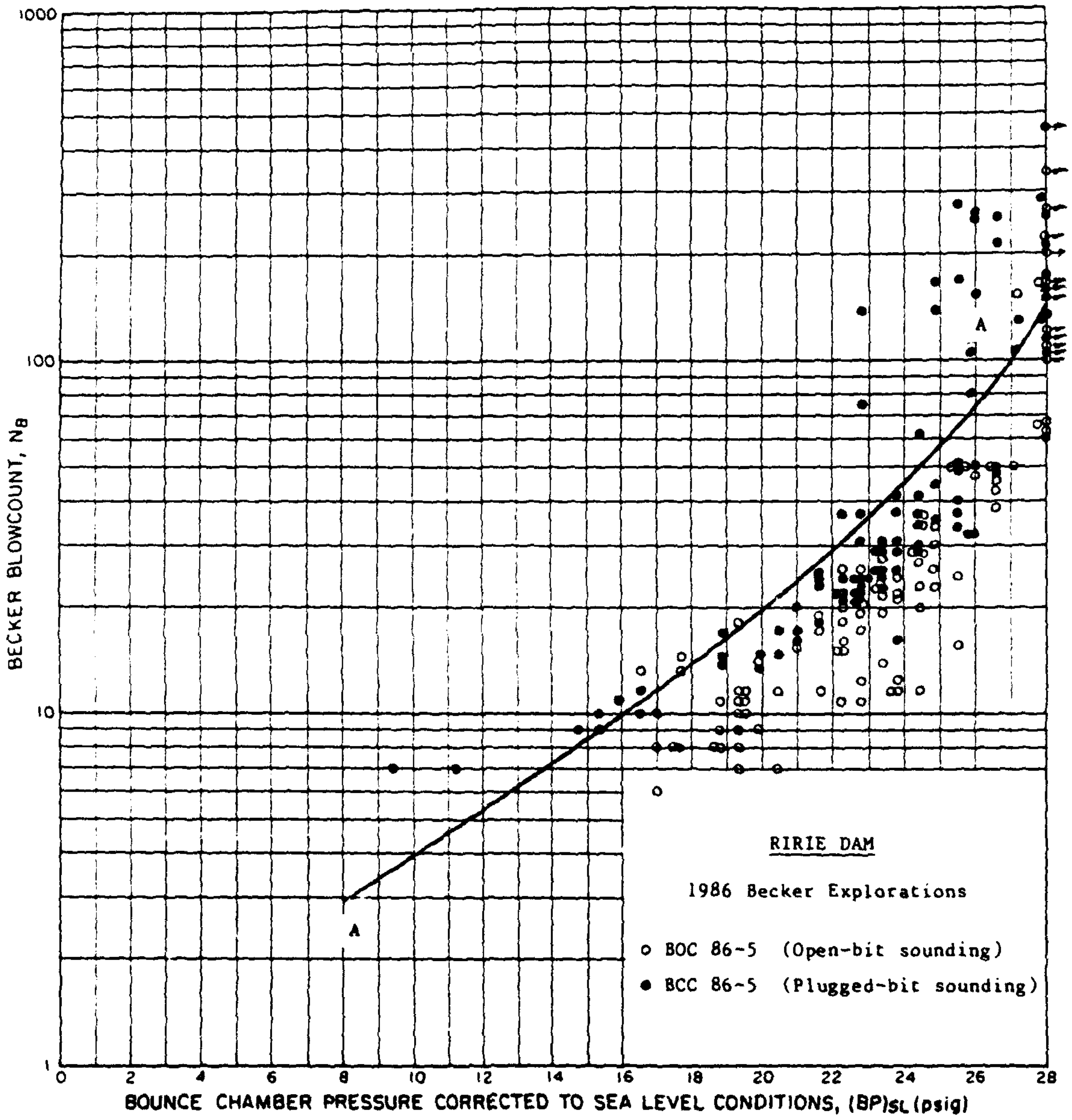

Figure E5. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 5

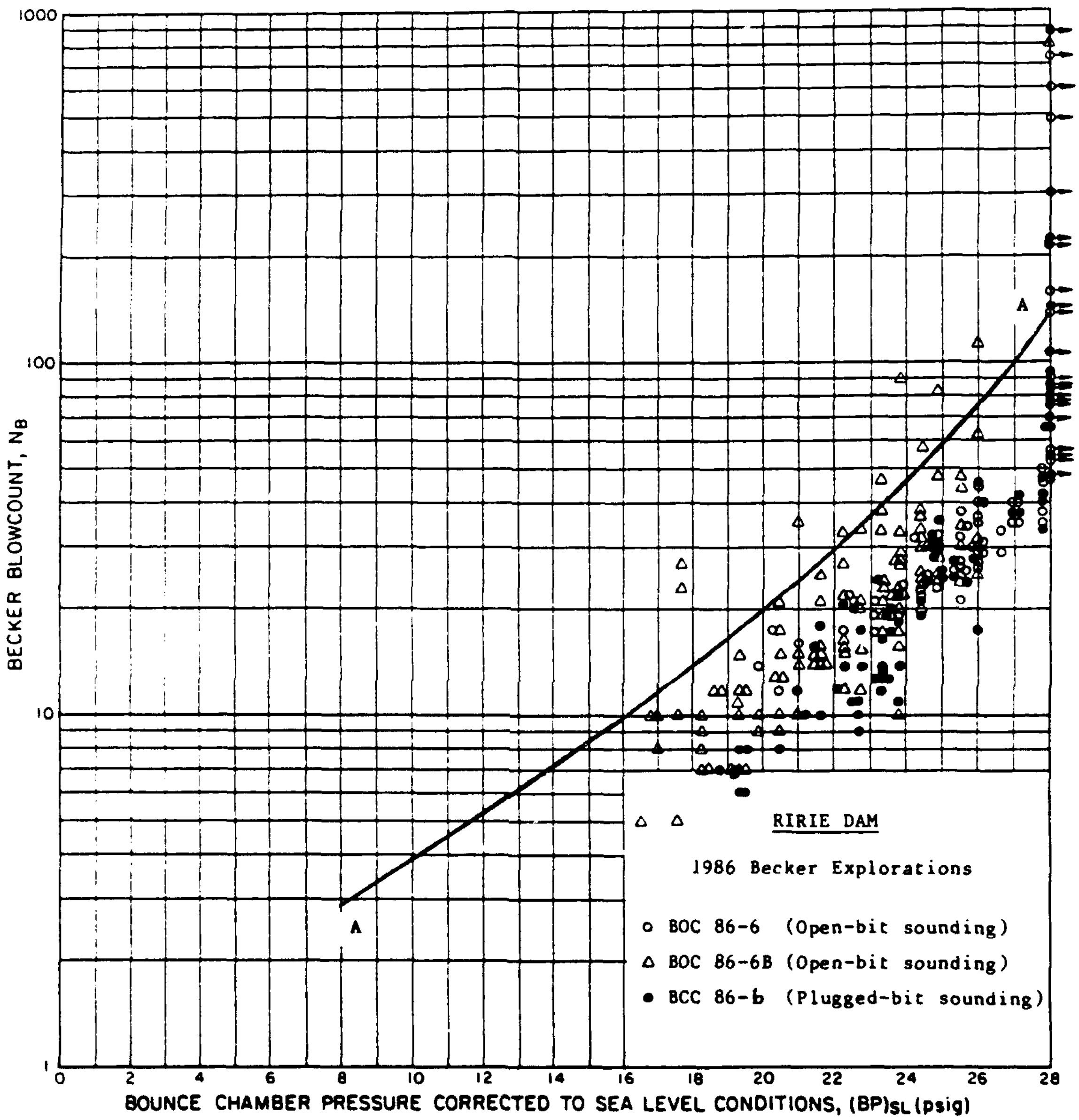

Figure E6. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 6

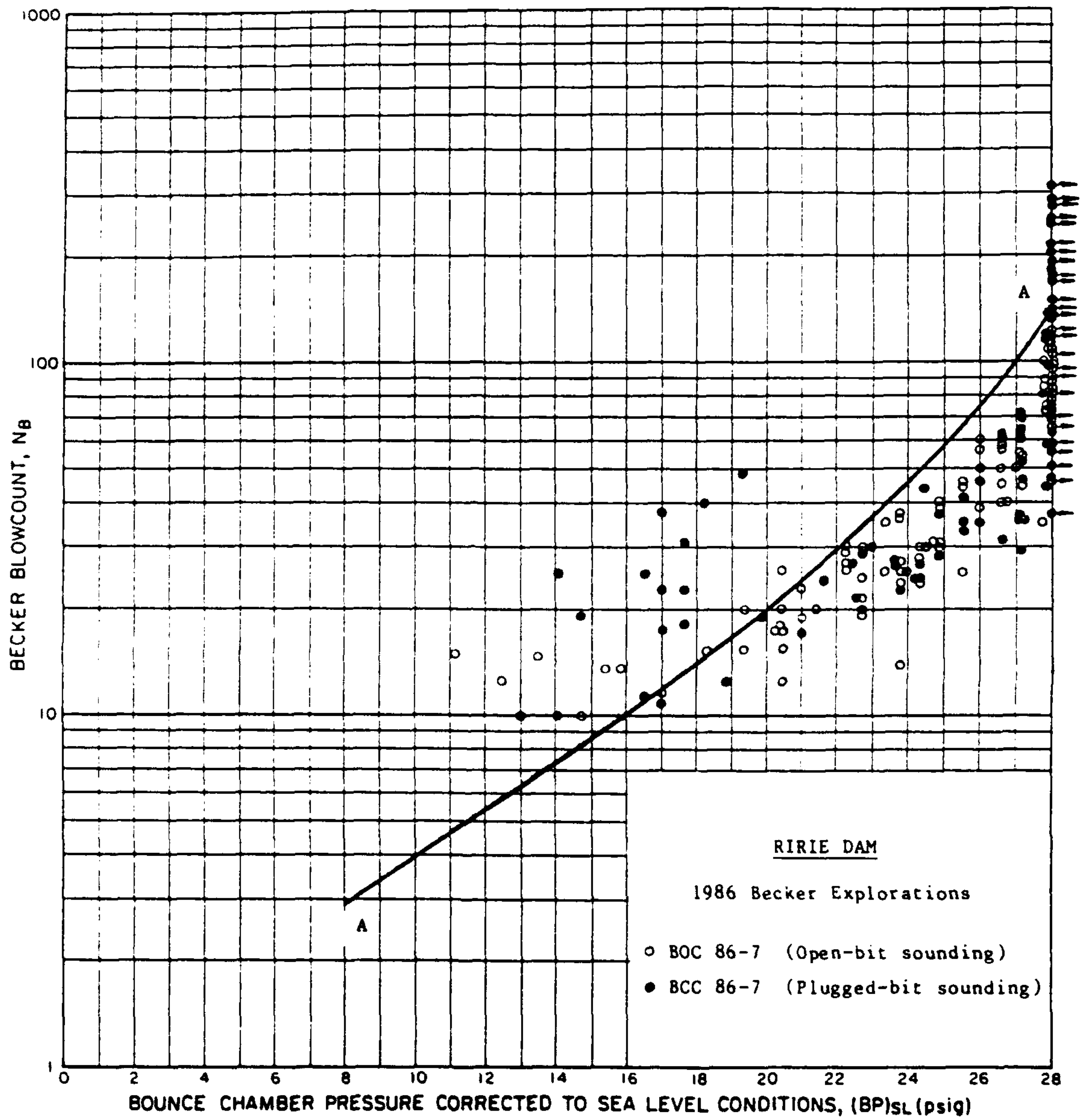

Figure E7. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 7

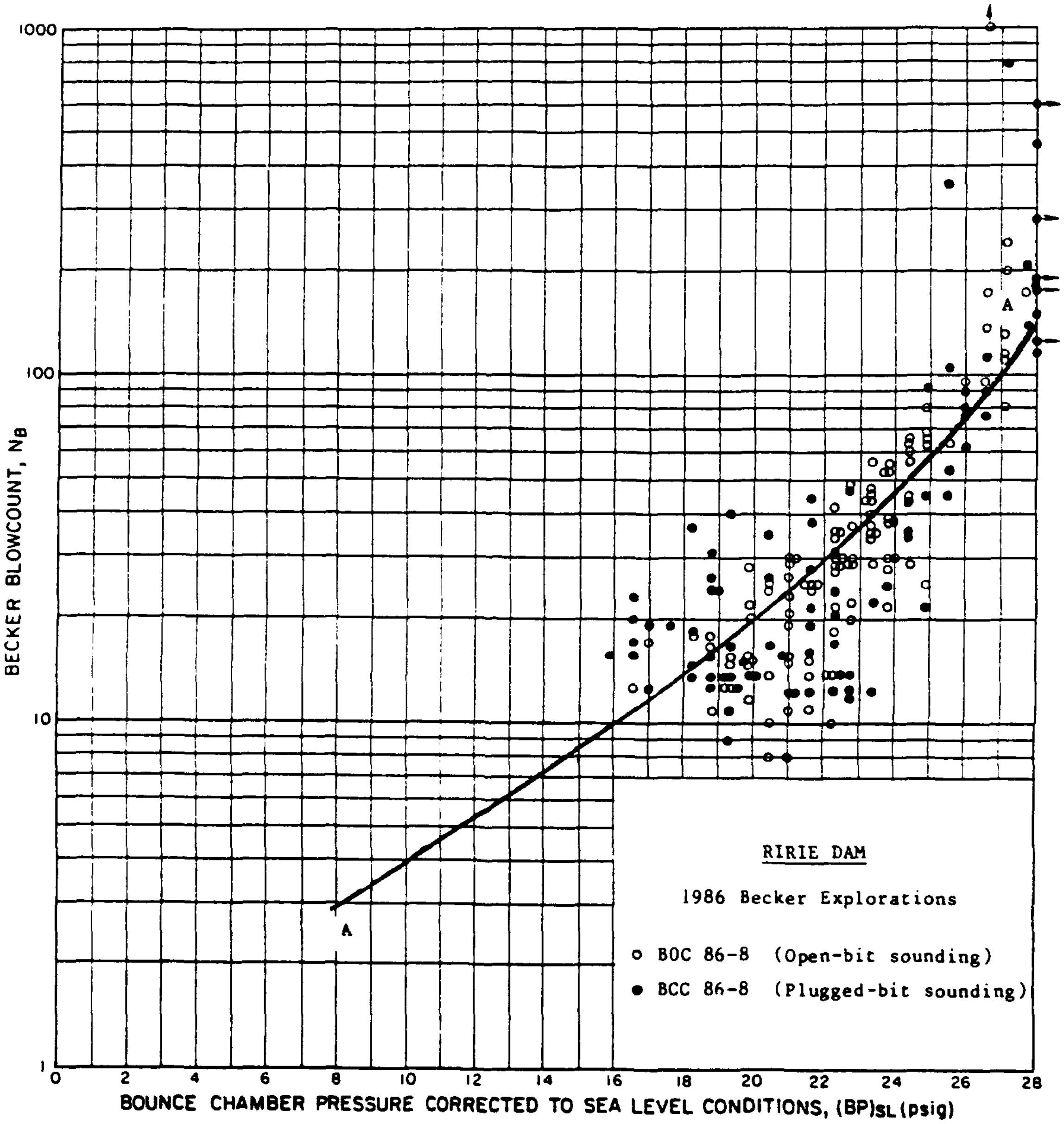

Figure E8. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 8

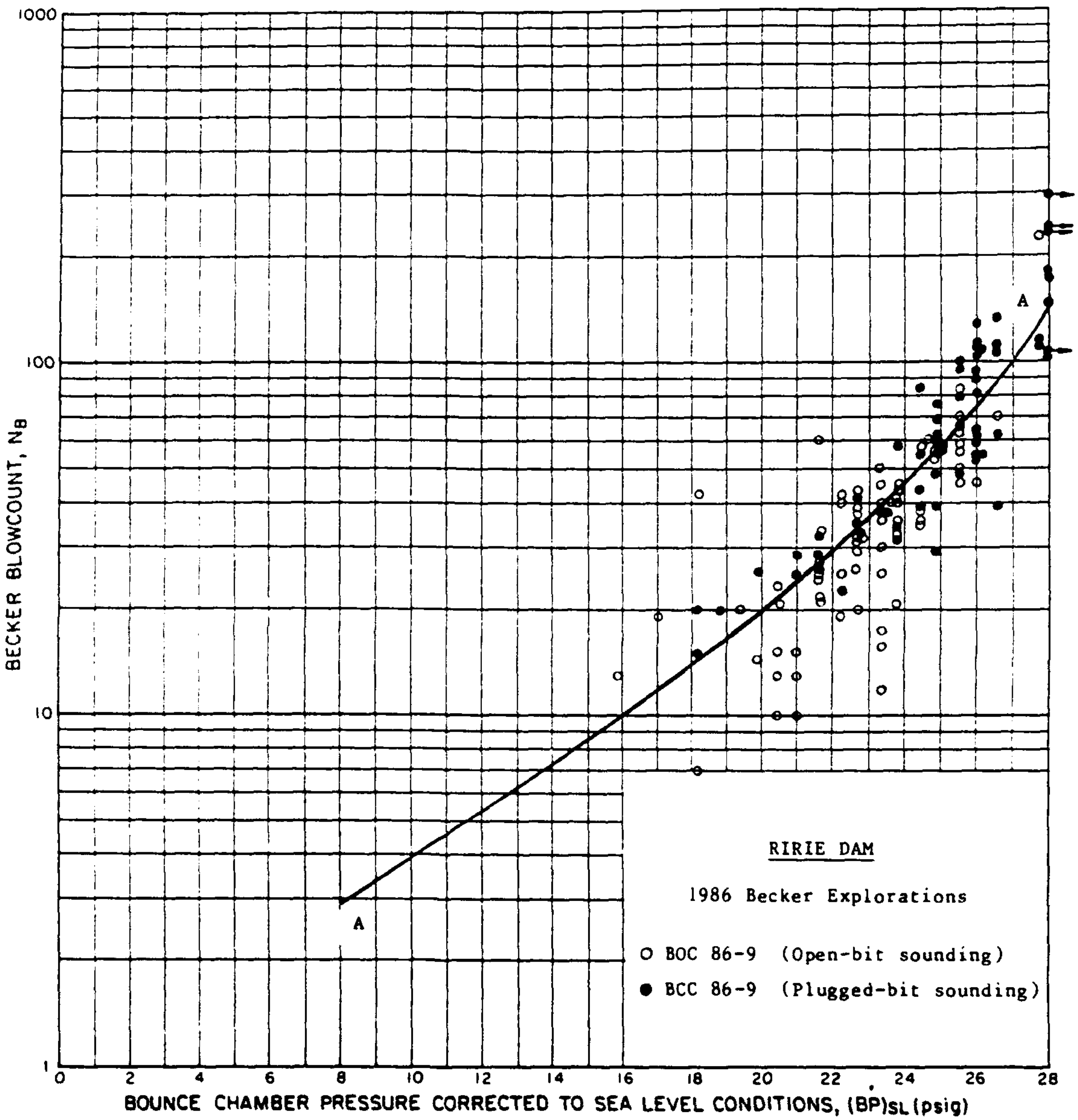

Figure E9. Relationship between corrected bounce chamber pressure and Becker blowcount measured at Ririe Dam--Drilling Site 9

Appendix F: Calculation Tables For Determining Equivalent SPT Blowcounts from Becker Data Obtained at Ririe Dam

RIRIE DAM

BCC 86-1

DEPTH (feet)	N_B	BP	BP_c	N_{BC}	N_{60}
1					
2	11	15	19.3	13	13 (9.8)
3	10	11½	15.5	9½	9½ (7.1)
4	12	13	17.0	12	12 (9)
5	8	12½	16.5	9½	9½ (7.1)
6	9	12	15.4	9½	9½ (7.1)
7	15	13½	17.6	14½	14½ (10.9)
8	19	16½	21	20½	19½ (14.6)
9	17	16½	21	19	18½
10	11	15	19.3	13	13
11	22	18	22.7	29½	22½
12	12	15	19.3	13½	13½
13	11	14	18.2	12	12
14	11	13	17.0	11½	11½
15	9	23	23.2	14½	14½
16	43	19½	24.4	44	26
17	22	18	22.7	29½	22½
18	68	22½	27.7	76	56
19	381	22½	27.7	>300	>150
20	115	22	27.1	>300	>150
21	183	22	27.1	170	113
22	101	23	28.2	104	73
23	37	19	23.8	38	31½
24	25	17½	22.2	26	23½
25	20	17½	22.2	23	21½
26	29	19½	24.4	33	28
27	35	20	24.4	38½	32
28	45	21	26	49	39
29	33	21	26	37½	31½
30	33	21	26	37½	31½
31	36	20½	25.5	40	33
32	34	19½	24.4	37	31
33	34	20	24.9	38	31½
34	44	21	26	48	38½
35	56	23½	28.8	66	50
36	70	25	30.4	83	60
37	114	24½	29.9	118	80
38	146	24½	29.9	160	107
39	129	24½	29.9	143	96
40	127	23½	28.8	135	91

BCC-1

N_B	BP	BP_c	N_{BC}	N_{60}	DEPTH (FEET)
117	24	29.3	125	85	41
109	23½	28.8	116	80	
86	23	28.2	93	66	
62	23	28.2	70	52	
58	22	27.1	63	48	
45	22½	27.7	42	34½	
79	24	29.3	90	64	
142	24½	29.9	150	100	
120	23½	28.8	126	86	
84	22	27.1	86	62	50
63	21½	26.6	67	50½	
44	21	26	48½	38½	
29	21	26	34	29	
31	21	26	36	30½	
78	22½	27.7	84	60½	
92	23	28.2	99	69½	
64	21½	26.6	68	51	
56	22	27.1	62	47½	
45	21½	26.6	51	40½	
39	21	26	43	35	60
38	21	26	42	34½	
43	21½	26.6	47	38	
67	21½	26.6	71	53	
62	21	26	6[illegible]	48½	
114	22	27.1	112	77	
192	22	27.1	173	115	
230	22½	27.7	210	132	
426	22½	27.7	>300	>150	
774	22	27.1	>300	>150	
1440	22	27.1	>300	>150	70
1570	21	26	>300	>150	
					80

RIRIE DAM

DEPTH (feet)	BCC 86-2 N_B	BCC 86-2 BP	BCC 86-2 BP_c	BCC 86-2 N_{BC}	BCC 86-2 N_{60}	BOC 86-2 N_B	BOC 86-2 BP	BOC 86-2 BP_c	BOC 86-2 N_{BC}	BOC 86-2 N_{60}	BCC 86-3 N_B	BCC 86-3 BP	BCC 86-3 BP_c	BCC 86-3 N_{BC}	BCC 86-3 N_{60}	BOC 86-3 N_B	BOC 86-3 BP	BOC 86-3 BP_c	BOC 86-3 N_{BC}	BOC 86-3 N_{60}
1						17	15	19.3	17	16½						14	10	13.5	9	9
2	29	23	28.2	36	30½	9	12½	16.5	10	10	29	18½	23.3	31	27	5	10	13.5	6	6
3	50	21	26.0	53	41½	14	20	24.9	19	18½	38	20½	25.5	42	34½	4	15	19.3	7½	7½
4	21	16	20.4	21	20	15	15½	19.9	16½	16½	12	15	19.3	13½	13½	12	16½	21	15	15
5	9	13½	17.6	10½	10½	11	14	18.2	12	12	19	15½	19.9	19	18½	9	17½	22.2	13	13
6	7	13	17.0	9	9	12	13	17.0	12	12	24	16	20.4	23½	22	12	13½	17.6	12½	12½
7	10	17½	22.2	13½	13½	10	12½	16.5	10½	10½	22	15½	19.9	21	20	13	14½	18.8	14	14
8	23	17½	22.2	25	23	11	11½	15.3	10	10	28	15½	19.9	26	23½	15	16½	21	17	16½
9	22	19	23.8	26	23½	25	22	27.1	32	27½	59	17	21.6	50	40	13	14	18.2	13½	13½
10	32	19	23.8	34	29	34	21½	26.6	39	32½	31	16	20.4	28	25	11	16	20.4	13½	13½
11	22	17	21.6	23½	22	25	19½	24.4	29	25½	18	15	19.3	17½	17	10	15	19.3	12½	12½
12	20	16½	21.0	21	20	15	16	20.4	17	16½	14	15	19.3	15	15	11	12½	16.5	11	11
13	16	16½	21.0	18	17½	10	14	18.2	11½	11½	11	14½	18.8	12½	12½	11	13½	17.6	12	12
14	21	17	21.6	22½	21	14	16	20.4	16	16	9	14½	18.8	11½	11½	11	13½	17.6	12	12
15	25	16	20.4	24	22	28	20	24.9	32	27½	7	13	17.0	9	9	9	14	18.2	11	11
16	17	15	19.3	17	16½	16	16½	21.0	18	17½	7	12½	16.5	8½	8½	11	13½	17.6	12	12
17	12	14½	18.8	13½	13½	15	16	20.4	17	16½	6	12½	16.5	8	8	11	13½	17.6	12	12
18	12	14	18.2	13	13	14	15	19.3	15	15	6	12½	16.5	8	8	10	12½	16.5	10½	10½
19	11	14½	18.8	12½	12½	17	17½	22.2	20	19	7	13½	17.6	9	9	10	13½	17.6	11	11
20	11	14	18.2	12	12	16	17½	22.2	19	18½	6	13½	17.6	8½	8½	8	13½	17.6	10	10
21	10	14	18.2	11½	11½	15	16	20.4	17	16½	9	15	19.3	11½	11½	7	14	18.2	9½	9½
22	10	14	18.2	11½	11½	13	15½	19.9	15	15	22	18	22.7	24½	22½	7	14½	18.8	10	10
23	10	13½	17.6	11½	11½	12	16	20.4	14½	14½	27	19	23.8	30	26	9	12½	16.5	10	10
24	9	13	17.0	10	10	15	16	20.4	17	16½	24	18	22.7	26	23½	7	12½	16.5	8½	8½
25	7	13	17.0	9	9	22	17	21.6	23½	22	21	17½	22.2	23	21½	6	13	17.0	8	8
26	7	13	17.0	9	9	26	17½	22.2	27	24½	18	17	21.6	20½	19½	7	12½	16.5	8½	8½
27	8	13	17.0	9½	9½	18	16½	21.0	20	19	18	17	21.6	20½	19½	6	13	17.0	8	8
28	13	14½	18.8	14	14	19	17	21.6	21	20	16	17	21.6	18½	18	6	14	18.2	9	9
29	12	15	19.3	13½	13½	17	17½	22.2	20	19	11	14	18.2	12	12	15	16	20.4	17	16½
30	17	17	21.6	19½	18½	25	19	23.8	28	25	9	15	19.3	11½	11½	15	16½	21	17	16½
31	29	18½	23.3	31	27	25	18½	23.3	27½	24½	11	15	19.3	13	13	16	17	21.6	18	17½
32	18	17	21.6	20½	19½	18	15½	19.9	18½	18	21	18	22.7	24	22	25	20	24.9	30	26
33	10	15	19.3	12½	12½	13	17	21.6	16	16	32	19½	24.4	35	29½	26	20	24.9	30½	26½
34	9	14	18.2	11	11	15	16½	21.0	17	16½	29	18½	23.3	31	27	29	20	24.9	33	28
35	8	14	18.2	10	10	15	16	20.4	17	16½	26	18½	23.3	28	25	34	21	26	39	32½
36	9	14	18.2	11	11	14	15½	19.9	16	16	31	19½	24.4	34	29	28	20	24.9	32½	28
37	9	14½	18.8	11½	11½	12	15	19.3	13½	13½	36	20	24.9	31	27	30	20	24.9	34	29
38	10	14½	18.8	12	12	9	14	18.2	11	11	53	21½	26.6	58	45	50	22	27.1	56	43½
39	9	15	19.3	11½	11½	11	16	20.4	13½	13½	57	22½	27.7	65	49	48	23½	28.8	58	45
40	8	15	19.3	11	11	11	15½	19.9	13½	13½	55	22½	27.7	63	48	48	22½	27.7	56	43½

	BCC 86-2					BOC 86-2					BCC 86-3					BOC 86-3					DEPTH (feet)
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	
41	8	14½	18.8	10½	10½	11	16	20.4	13½	13½	76	24½	29.9	90	64	63	22½	27.7	69	51½	41
42	9	15½	19.5	11½	11½	12	16½	21	15	15	104	25½	31.0	115	79	60	23½	28.8	68	51	2
43	10	15½	19.5	12½	12½	54	19	23.8	55	43	128	25½	31.0	145	97	61	22½	27.7	68	51	3
44	35	20	24.9	38	31½	70	23	28.2	77	56½	134	25	30.4	145	97	61	22½	27.7	68	51	4
45	39	20	24.9	42	34½	68	23	28.2	75	55	149	25	30.4	165	110	55	21½	26.6	60	46	5
46	40	20½	25.5	43	35	55	21½	26.6	60	46	128	24	29.3	140	94	50	22	27.1	56	43½	6
47	34	20½	25.5	39	32½	25	18½	23.3	28	25	130	24	29.3	140	94	45	22	27.1	50	40	7
48	19	17	21.6	21	20	23	18½	23.3	26	23½	168	25	30.4	180	119	46	22½	27.7	51	40½	8
49	20	17½	22.2	22½	21	19	18½	23.3	23	21½	156	25	30.4	170	113	57	20	24.9	57	44	9
50	40	20	24.9	43	35	15	18½	23.3	19	18½	121	24	29.3	135	91	26	20½	25.5	31½	27½	50
51	30	19	23.8	33	28	15	19	23.8	20	19	86	22½	27.7	92	65½	26	19½	24.4	30	26	11
52	19	18½	23.3	23	21½	20	19½	24.4	24	22	64	21½	26.6	68	51	35	22	27.1	41	33½	12
53	43	20½	25.5	46	37	35	21½	26.6	40	33	70	22½	27.7	76	56	43	22	27.1	48	38½	13
54	53	20½	25.5	55	43	80	23	28.2	88	63	64	22½	27.7	70	52	40	21½	26.6	45	36½	14
55	24	18½	23.3	27	24½	50	21½	26.6	55	43	67	22½	27.7	74	54½	42	21½	26.6	47	38	15
56	20	18	22.7	23	21½	40	20½	25.5	43	35	71	22½	27.7	76	56	36	20½	25.5	40	33	16
57	30	19½	24.4	33	28	27	19	23.8	30	26	45	21	26.0	49	39	35	20½	25.1	38½	32	17
58	37	20½	25.5	41	33½	19	18½	23.3	23	21½	21	18	22.7	24	22	26	18½	23.3	24	22	18
59	27	19½	24.4	32	27½	19	17½	22.2	22	20½	13	19½	24.4	18	17½	29	20	24.9	33½	28½	19
60	65	21½	26.6	69	51½	14	17	21.6	17	16½	26	20	24.9	31	27	40	21	26	44	36	60
61	93	22½	27.7	99	69½	16	17½	22.2	19	18½	26	19	23.8	29	25½	43	20	24.9	45	36½	21
62	123	23	28.2	125	85	23	18½	23.3	26	23½	18	17½	22.2	21	20	30	20	24.9	34	29	22
63	[illegible]	22½	27.7	102	71	23	19	23.8	27	24½	13	17	21.6	16	16	40	20	24.9	43	35	23
64	71	21	26.0	73	54	16	18	22.7	20	19	33	19	23.8	35	29½	45	20	24.9	47	38	24
65	60	21½	26.6	65	49	30	19½	24.4	33	28	53	21	26.0	57	44	54	21	26	57	44	25
66	[illegible]	21½	26.6	95	67	20	17½	22.2	22½	21	41	20½	25.5	45	36½	45	21	26	49	39	26
67	89	22½	27.7	94	66½	21	19½	24.4	25½	23	29	22	27.1	35½	30	50	21½	26.6	55	43	27
68	67	22½	27.7	73	54	15	18½	23.3	19	18½	125	23½	28.8	130	88	47	22½	27.7	59	42½	28
69	197	23½	28.8	190	125						180	23	28.2	175	116	43	19½	24.4	44	36	29
70	110	23½	28.8	117	80						135	22	27.1	130	88	38	19½	24.4	40	33	70
71	275	24½	29.9	270	130						100	22	27.1	100	70	36	21½	26.6	41	33½	31
72											89	21½	26.6	89	63½	55	22	27.1	61	47	32
73											107	22½	27.7	110	76	72	22½	27.7	78	57	33
74											137	23	28.2	137	92	96	22½	27.7	100	70	34
75											146	23½	28.8	150	100	83	21½	26.6	89	60½	35
76											98	22	27.1	99	69½	50	21½	26.6	55	43	36
77											60	21½	26.6	64	48½	53	21½	26.6	58	45	37
78											52	21½	26.6	57	44	49	20	24.9	50	40	38
79											42	20	24.9	44	36	22	19	23.8	26	23½	39
80											29	19½	24.4	23	21½	33	20½	25.5	37	31	80
											33	20	24.9	36	30½	40	21	26	44	36	
											68	23½	28.8	76	56	57	21½	26.6	62	47½	
																107	23	28.2	107	72	

RIRIE D[illegible]

DEPTH (feet)	BCC-4 N_B	BCC-4 BP	BCC-4 BP_c	BCC-4 N_{BC}	BCC-4 N_{60}	BOC-4 N_B	BOC-4 BP	BOC-4 BP_c	BOC-4 N_{BC}	BOC-4 N_{60}
1		11½	15.3				10	13.5		
2	12	17	21.6	15	15 (11.3)	10	10	13.5	8	8 (8.6)
3	13	13½	17.6	13	13 (12.8)	13	11	14.7	10	10 (7.5)
4	16	14½	18.8	16	16 (12)	11	12½	16.5	11	11 (8.3)
5	17	15½	19.9	18	17½ (13.1)	21	17½	22.2	23	21½ (16.1)
6	23	15½	19.9	21½	20 (15.0)	20	18½	23.3	23½	22 (16.5)
7	17	14	18.2	16	16 (12)	35	17	21.6	35	29½ (22.1)
8	16	14	18.2	15½	15½ (11.6)	18	14½	18.8	17	16½ (12.4)
9	13	17½	22.2	16½	16½	18	16½	21.0	20	19
10	11	14	18.2	12	12	19	17	21.6	21	20
11	11	13½	17.6	11½	11½	17	16	20.4	18	17½
12	13	13½	17.6	13	13	63	19	23.8	60	46
13	19	15½	19.9	19	18½	45	20	24.9	46	37
14	31	18½	23.3	33	28	22	16½	21.0	22½	21
15	40	18	22.7	39	32½	17	16½	21.0	19	18½
16	45	18½	23.3	43½	35½	28	19	23.8	31	27
17	36	18	22.7	35½	30	41	21	26.0	45	36½
18	29	18½	23.3	31	27	52	21½	26.6	57	44
19	26	18½	23.3	28	25	42	19	23.8	42½	35
20	26	18½	23.3	28	25	25	17½	22.2	26	23½
21	29	18½	23.3	31	27	40	19	23.8	41	33½
22	40	21	26.0	44	36	57	21½	26.6	61	47
23	37	21	26.0	42	34½	57	20½	25.5	59	45½
24	34	20	24.9	37	31	59	21	26.0	62	47½
25	24	19	23.8	27	24½	48	20½	25.5	50	40
26	30	20½	25.5	35	29½	40	19½	24.4	42	34½
27	58	22½	27.7	65	49	37	19½	24.4	39	32½
28	51	20½	25.5	53	41½	32	19	23.8	34	29
29	44	22	27.1	50	40	45	20	24.9	47	38
30	49	22½	27.7	56	43½	46	20	24.9	47½	38
31	34	20½	25.5	38	31½	41	20	24.9	43	35
32	20	18	22.7	23	21½	44	20	24.9	46	37
33	19	17	21.6	21	20	37	19½	24.4	39	32½
34	13	15½	19.9	15	15	23	18½	23.3	26	23½
35	17	17½	22.2	20	19	17	16	20.4	18½	18
36	29	20	24.9	33½	28½	25	17½	22.2	26	23½
37	43	21½	26.6	48	38½	30	18½	23.3	32	27½
38	34	20½	25.5	38	31½	34	19½	24.4	36	30½
39	37	21½	26.6	43	35	40	21½	26.6	45	36½
40	52	22½	27.7	59	45½	28	20½	25.5	33	28

DEPTH (feet)	BCC-5 N_B	BCC-5 BP	BCC-5 BP_c	BCC-5 N_{BC}	BCC-5 N_{60}	BOC-5 N_B	BOC-5 BP	BOC-5 BP_c	BOC-5 N_{BC}	BOC-5 N_{60}
1		16.5	21.0							
2	17	19½	18.8	16½	16½ (12.4)	5	15	19.3	8½	8½ (6.4)
3	11	12	15.9	10½	10½ (7.9)	12	15	19.3	13½	13½ ([illegible])
4	9	11	14.7	8½	8½ (6.4)	11	15	19.3	13	13 (9.8)
5	9	11½	15.3	9	9 (6.8)	8	13	17.0	9½	9½ (7.1)
6	10	12½	16.5	10½	10½ (7.9)	6	13	17.0	8	8 (6.0)
7	10	11½	15.3	9½	9½ (7.1)	8	13½	17.6	10	10 (7.5)
8	7	6½	9.4	5	5 (3.8)	10	15	19.3	12½	12½ (9.4)
9	12	12½	16.5	11½	11½	11	17½	22.2	14½	14½
10	26	19	23.8	29	25½	24	19	23.8	28	25
11	30	19½	24.4	33	28	23	18½	23.3	26	23½
12	24	17½	22.2	26	23½	21	19	23.8	25	23
13	15	14½	18.8	15½	15½	27	19½	24.4	31	27
14	14	14½	18.8	15	15	22	18½	23.3	25	23
15	19	15	19.3	11½	11½	29	19½	24.4	32½	28
16	10	13	17.0	11	11	28	18½	23.3	30	26
17	8	13½	17.6	10	10	26	17½	22.2	27	24½
18	7	8	11.2	5½	5½	19	18	22.7	22½	21
19	16	19	23.8	21	20	23	19½	24.4	28	25
20	22	18	22.7	24	22	22	19	23.8	26	23½
21	20	16½	21.0	21	20	20	17½	22.2	22½	21
22	18	17	21.6	20½	19½	18	17½	22.2	21	20
23	16	16½	21.0	18	17½	21	18	22.7	24	22
24	29	19	23.8	32	27½	18	17	21.6	20½	19½
25	24	17	21.6	25	23	24	18½	23.3	27	24½
26	23	17	21.6	24	22	29	19½	24.4	32½	28
27	25	17	21.6	26	23½	37	19½	24.4	39	32½
28	17	16	20.4	18	17½	35	19½	24.4	37	31
29	15	16	20.4	16½	16½	30	18½	23.3	32	27½
30	15	15½	19.9	16½	16½	15	17½	22.2	18	17½
31	17	16½	21.0	19	18½	24	20½	25.5	29	25½
32	14	15½	19.9	15½	15½	26	20	24.9	30½	26½
33	29	18½	23.3	31	27	26	18	22.7	28	25
34	29	18½	23.3	31	27	16	16½	21.0	18	17½
35	26	18½	23.3	29	25½	17	17	21.6	19½	18½
36	37	19½	24.4	39	32½	19	18½	23.3	23	21½
37	50	21	26.0	54	42½	14	18½	23.3	18	17½
38	49	20½	25.5	51	40½	17	18	22.7	21	20
39	31	19	23.8	33	28	16	17½	22.2	19½	18½
40	22	17½	22.2	24	22	15	17½	22.2	18	17½

BCC-4					BOC-4					BCC-5					BOC-5					
N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	DEPTH (feet)
42	22	27.1	48	38½	32	20½	25.5	36	30½	22	17½	22.2	24	22	12	17	21.6	15	15	41
44	22½	27.7	51	40½	65	23½	28.8	75	55	22	18	22.7	24½	22½	11	15	19.3	13	13	
40	22	27.1	46	37	63	20½	25.5	63	48	23	18	22.7	25	23	12	16	20.4	14½	14½	
34	20½	25.5	38	31½	30	17½	22.2	30	26	24	18	22.7	26	23½	15	15½	19.9	16½	16½	
27	20½	25.5	34	29	24	17	21.6	25	23	24	18	22.7	26	23½	8	15	19.3	11	11	
30	20½	25.5	35	29½	24	17½	22.2	25½	23	24	18	22.7	26	23½	9	15½	19.9	12	12	
33	20½	25.5	37	31	27	16½	21.0	26	23½	22	18	22.7	24½	22½	7	15	19.3	10	10	
30	20	24.9	34	29	31	17½	22.2	31	27	21	17½	22.2	23	21½	7	16	20.4	10½	10½	
50	22½	27.7	57	44	35	19½	24.4	38	31½	21	18	22.7	24	22	12	15	19.3	13½	13½	
44	22½	27.7	50½	40	20	18	22.7	23	21½	26	18½	23.3	29	25½	8	14½	18.8	10½	10½	50
38	22	27.1	44	36	28	18½	23.3	30	26	23	18½	23.3	26	23½	8	14½	18.8	10½	10½	
55	22½	27.7	63	48	49	19½	24.4	49	39	25	18½	23.3	28	25	10	15	19.3	12½	12½	
70	23½	28.8	79	57½	43	19	23.8	43	35	29	19½	24.4	33	28	9	14½	18.8	11½	11½	
60	23½	28.8	69	51½	45	19	23.8	45	36½	35	20	24.9	38	31½	11	14½	18.8	12½	12½	
56	23	28.2	65	49	44	19	23.8	44	36	34	19½	24.4	37	31	15	13½	17.6	14	14	
57	24	29.3	68	51	45	18½	23.3	44	36	31	18	22.7	31½	27½	14	13½	17.6	13½	13½	
82	25	30.4	88	63	42	18	22.7	40	33	31	18½	23.3	32	27½	14	12½	16.5	12½	12½	
85	24½	29.9	90	64	37	19½	24.4	39	32½	41	19½	24.4	42	34½	18	15	19.3	17½	17½	
102	24	29.3	115	79	73	20	24.9	70	52	51	20½	25.5	54	42½	38	21½	26.6	44	36	
163	25	30.4	175	116	80	20½	25.5	77	56½	62	19½	24.4	60	46	46	21½	26.6	50	40	60
180	25½	31	200	130	75	19½	24.4	70	52	80	20	24.9	75	55	50	21½	26.6	55	43	
83	24½	29.9	88	63	80	20½	25.5	77	56½	104	20	24.9	91	65	50	20½	25.5	53	41½	
71	24½	29.9	86	62	102	20½	25.5	94	66½	140	18	22.7	100	70	67	23	28.2	76	56	
67	24½	29.9	79	57½	90	20	24.9	82	59½	156	21	26.0	130	88	110	23½	28.8	117	80	
66	24	29.3	76	56	60	19½	24.4	58	45	173	20½	25.5	145	97	100	23½	28.8	108	74	
67	24	29.3	78	57	45	19½	24.4	46	37	142	20	24.9	117	80	218	25	30.4	230	130+	
56	23½	28.8	66	50	30	18	22.7	31	27	167	20	24.9	125	85	335	25	30.4	320	130+	
45	22	27.1	50	40	15	16	20.4	16½	16½	213	21½	26.6	180	119	265	25½	31.0	280	130+	
42	22	27.1	47	38	12	17½	22.2	12½	12½	246	21	26.0	195	128	170	23½	28.8	170	113	
42	22½	27.7	48	38½	25	15½	19.9	23½	22	273	20½	25.5	215	130+	170	22½	27.7	160	107	70
34	21½	26.6	39	32½	24	18½	23.3	27	24½	252	21	26.0	200	130	150	22	27.1	140	94	
30	21	26.0	35	29½	44	19	23.8	44	36	254	21½	26.6	210	130+	125	24	29.3	133	90	
36	21½	26.6	41	33½	50	18½	23.3	48	38½	189	22½	27.7	176	116	114	23½	28.8	124	85	
40	22	27.1	46	37	33	18½	23.3	34	29	160	24½	29.9	170	113	78	23½	28.8	88	63	
31	21½	26.6	36½	30½	57	20	24.9	57	44	118	23½	28.8	125	85	63	23	28.2	74	54½	
48	23	28.2	56	43½	75	20	24.9	71	53	155	23½	28.8	157	104	66	22½	27.7	74	54½	
88	24½	29.9	103	72	90	20½	25.5	84	60½	132	22½	27.7	130	88	50	22	27.1	56	43½	
85	22½	27.7	91	65	93	20	24.9	84	60½	131	22	27.1	125	85	42	21½	26.6	47	38	
68	22½	27.7	75	55	78	19½	24.4	72	53½	75	18	22.7	63	48	50	20½	25.5	53	41½	
69	23	28.2	76	56	76	19	23.8	68	51	41	19	23.8	41½	34	15	20½	25.5	21	20	80

RIRIE DAM

DEPTH (feet)	BCC-4					BOC-4					BCC-5					BOC-5				
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}
81	184	23½	28.8	94	66½	60	19	23.8	56	43½	32	21	26.0	37	31	23	20	24.9	18	17½
82	106	24	29.3	115	79	34	18	22.7	34	29	37	20½	25.5	41	33½	30	20	24.9	34	29
83	124	24½	29.9	135	91	25	17½	22.2	26	23½	44	20	24.9	46	37	12	19	23.8	16½	16½
84	131	25	30.7	146	97	24	17	21.6	25	23	34	20½	25.5	38	31½	13	19	23.8	17½	17
85	178	25½	31	200	130	84	19½	24.4	76	56	32	21	26.0	37	31	12	19½	24.4	17	16½
86	165	25	30.7	180	119	120	20	24.9	105	73	40	20½	25.5	43	35	13	18	22.7	17	16½
87	133	25	30.7	145	97	134	19½	24.4	108	74	50	21½	26.6	55	43	11	18	22.7	15	15
88	112	23	28.2	116	79	174	19½	24.4	133	90	37	17½	22.2	35	29½	12	19	23.8	16½	16½
89	106	23	28.2	112	77	140	20½	25.5	120	82	37	18	22.7	36	30½	20	19½	24.4	24	22
90	126	23½	28.8	132	89	135	21	26.0	120	82	38	19	23.8	39	32½	47	21	26.0	50	40
91	127	24	29.3	137	92	170	20½	25.5	140	94	48	21½	26.6	53	41½	35	20	24.9	39	32½
92	126	23½	28.8	132	89	130	20	24.9	110	76	60	23	28.2	58	45	200+	24½	29.9	210	130+
93	110	23	28.2	115	79	170	20½	25.5	140	94	105	22	27.1	105	73	1000+	25½	31.0	700+	130+
94	114	23	28.2	118	80	192	21	26.0	160	107	135	23	28.2	135	91					
95	83	23	28.2	91	65	132	20	24.9	110	76	104	24	29.3	115	79					
96	52	22½	27.7	60	46	123	20	24.9	105	73	174	23	28.2	168	112					
97	51	22½	27.7	59	45½	140	20	24.9	115	79	210	23	28.2	195	128					
98	43	21	26.0	47	38	150	20½	25.5	125	85	258	23	28.2	230	130+					
99	90	20	24.9	42½	35	100	20½	25.5	91	65	448	24	29.3	300	130+					
100	58	21½	26.6	63	48	110	21	26.0	102	71	500+	24	29.3	300+	130+					
101	84	22	27.1	88	63	103	21	26.0	96	67½										
102	105	22½	27.7	108	74	106	21	26.0	100	70										
103	112	24	29.3	123	84	140	21	26.0	123	84										
104	107	24½	29.9	122	83	187	21	26.0	158	105										
105	218	25	30.4	230	130+	260	20½	25.5	200	130										
106	290	25	30.4	290	130+	340	21	26.0	250	130+										
107	312	25	30.4	310	130+	320	21½	26.6	240	130+										
108						220	21	26.0	180	119										

RIRIE DAM

DEPTH (FEET)	BCC 86-6 N_S	BP	BR	N_{BC}	N_{60}	BOC 186-6 N_B	BP	BR	N_{BC}	N_{60}	BOC 186-6B N_B	BP	BR	N_{BC}	N_{60}
1						12	16	20.4	14½	19½		12	15.9		
2	24	18½	23.3	27	24½	17	17½	22.2	20	19	10	13	17.0	11	11
3	19	19½	24.4	24	22	16	16½	21.0	18	17½	15	15	19.3	16	16
4	21	17½	22.2	23	21½	14	15½	19.9	15½	15½	12	14½	18.8	13½	13½
5	14	18½	23.3	18	17½	17	16	20.4	18½	18	12	14½	18.8	13½	13½
6	18	17	21.6	20	19	22	17½	22.2	24	22	12	15	19.3	13½	13½
7	20	18	22.7	22	20½	32	19½	24.4	35	29½	8	13	17.0	9½	9½
8	27	20½	25.5	32	27½	44	21	26.0	48	38½	10	13	17.0	10½	10½
9	42	22½	27.7	49	39	25	21	26.0	31	27	10	14	18.2	11½	11½
10	25	19½	24.4	29	25½	19	19	23.8	23½	22	10	15	19.3	12	12
11	16	17	21.6	19	18½	25	20½	25.5	30	26	7	14	18.2	9½	9½
12	20	19	23.8	24	22	21	18½	23.3	24½	22½	9	14	18.2	11	11
13	17	21	26.0	23	21½	21	18	22.7	23½	22	8	14	18.2	10	10
14	35	20	24.9	38	31½	26	20½	25.5	31½	27½	10	13½	17.6	11	11
15	41	22	27.1	46	37	26	20½	25.5	31½	27½	5	12½	16.5	7½	7½
16	34	22½	27.7	41	33½	35	22	27.1	42	34½	7	15	19.3	10	10
17	47	25	30.4	60	46	46	22½	27.7	53	41½	10	15½	19.9	12½	12½
18	54	25½	31.0	68	51	35	22	27.1	42	34½	20	19	23.8	24	22
19	38	22	27.1	44	36	33	21½	26.6	39	32½	27	13½	17.6	20	19
20	41	22½	27.7	47	38	31	21	26.0	36½	30½	32	19½	24.4	35	29½
21	41	22½	27.7	47	38	34	20½	25.5	39	32½	38	19½	24.4	40	33
22	70	25	30.4	84	60½	40	22	27.1	47	38	25	20½	25.5	30	26
23	81	25	30.4	95	67	46	23	28.2	55	43	28	20	24.9	32½	28
24	87	25	30.4	99	69½	56	23½	28.8	65	49	34	20½	25.5	39	32½
25	75	23½	28.8	83	60	40	22	27.1	47	38	30	21	26.0	36	30½
26	65	23	28.2	73	54	37	20½	25.5	41	33½	25	21	26.0	31	27
27	78	24	29.3	87	62½	27	20½	25.5	31½	28	23	19½	24.4	28	25
28	65	23	28.2	73	54	26	21	26.0	32	27½	24	20½	25.5	29½	25½
29	40	21	26.0	45	36½	35	22	27.1	42	34½	30	19½	24.4	33	28
30	31	20	24.9	35	29½	37	22½	27.7	45	36½	16	19	23.8	21	20
31	28	20	24.9	32½	28	29	21½	26.6	35½	30	13	16	20.4	15½	15½
32	25	20	24.9	30	26	29	21	26.0	35	29½	7	15	19.3	10	10
33	29	20	24.9	33½	28½	25	19½	24.4	29	25½	7	15	19.3	10	10
34	46	23	28.3	55	43	22	19½	24.4	26½	24	12	15	19.3	13½	13½
35	21	18½	[illegible]	25½	23	23	19½	24.4	27½	24½	24	18½	23.3	27	24½
36	24	20½	25.5	29½	25½	21	20½	25.5	27	24	22	19	23.8	26	23½
37	25	20½	25.5	30	26	35	22½	27.7	43	35	22	19	23.8	26	23½
38	28	21	26.0	34	29	53	24	29.3	63	48	24	20	24.9	29	25½
39	38	22	27.1	45	36½	50	22½	27.7	58	45	33	19	23.8	35	29½
40	24	20	24.9	28½	25	40	21	26.0	45	36½	30	20½	25.5	35	29½

BCC 86-6					BOC 86-6					BOC 86-6B					DEPTH (feet)
N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	
19	18.5	23.3	23	21½	30	21	26.0	36	30½	22	19	23.8	26	23½	41
14	17.5	22.2	17½	17	29	21	26.0	35	29½	24	19½	24.4	28	25	
10	16.5	21.0	13	13	19	19	23.8	23½	22	17	18½	23.3	21	20	
8	16	20.4	11½	11½	17	18½	23.3	21	20	21	18	22.7	24	22	
8	15	19.3	10½	10½	19	18½	23.3	23	21½	20	18	22.7	23	21½	
6	15	19.3	9	9	23	20	24.9	28	25	15	17½	22.2	18½	18	
6	15	19.3	9	9	25	19½	24.4	29	25½	16	17½	22.2	19½	18½	
7	15	19.3	10	10	35	21	26.0	40	33	14	17	21.6	17	16½	
8	15	19.3	10½	10½	32	20½	25.5	37	31	14	16½	21.0	17	16½	
7	14½	18.8	10	10	36	21	26.0	41	33½	9	15½	19.9	12	12	50
7	15	19.3	10	10	32	20	24.9	36	30½	10	16½	21.0	13	13	
32	20	24.9	36	30½	23	19	23.8	27	24½	9	16	20.4	12	12	
22	19	23.8	26	23½	165	24½	29.9	175	116	11	15	19.3	13	13	
12	16½	21.0	15	15	90	24½	29.9	100	70	15	16	20.4	17	16½	
30	20	24.9	34	29	140	25½	31.0	150	100	23	13½	17.6	18	17½	
142	23½	28.8	147	98	490	26	31.5	300+	130+	38	18½	23.3	38	31½	
212	25	30.4	220	130+	600	24½	29.9	500+	130+	37	19½	24.4	40	33	
104	24½	29.9	116	79	300	26	31.5	300+	130+	29	19	23.8	32	27½	
44	21	26.0	48	38½	730	25	30.4	500+	130+	32	21	26.0	37½	31½	
14	18	22.7	18	17½	1450	26	31.5	500+	130+	35	16½	21.0	32	27½	60
17	18½	23.3	21	20						10	16	20.4	13	13	
31	20	24.9	35	29½						10	19	23.8	15	15	
19	19	23.8	23	21½						25	19½	24.4	29	25½	
10	17	21.6	13½	13½						12	18	22.7	16½	16½	
12	17½	22.2	16	16						7	14	18.2	9½	9½	
9	18	22.7	13½	13½						5	13½	17.6	7½	7½	
13	18½	23.3	17½	17						17	16	20.4	18½	18	
18	18	22.7	21½	20						27	17½	22.2	28	25	
13	18½	23.3	17½	17						15	18	22.7	19	18½	
10	18	22.7	14½	14½						21	16	20.4	21	20	70
11	18	22.7	15	15						34	18	22.7	34	29	
11	18	22.7	15	15						22	17½	22.2	24½	22½	
12	18½	23.3	16½	16½						13	16	20.4	15½	15½	
14	19	23.8	19	18½						15	16½	21.0	17½	17	
11	19	23.8	16	16						15	17½	22.2	18½	18	
13	18½	23.3	17½	17						14	17	21.6	17	16½	
13	18½	23.3	17½	17						15	17	21.6	18	17½	
17	19	23.8	21½	20						21	17	21.6	22½	21	
92	23	28.2	97	68						14	17	21.6	17	16½	
89	23½	28.8	97	68						33	17½	22.2	32½	28	80

DEPTH (feet)	BCC-86-6					BOC 86-6					BOC 86-6B				
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}
81	216	25	30.4	225	130+						46	18½	23.3	44	36
82	870	25½	31.0	500+	130+						89	19	23.8	76	56
83	1000+	25½	31.0	500+	130+						83	20	24.9	77	56½
84											57	19½	24.4	56	43½
85											34	18½	23.3	35	29½
86											15	17	21.6	18	17½
87											14	17	21.6	17	16½
88											12	17½	22.2	16	16
89											25	17	21.6	25½	23
90											25	20	24.9	30	26
91											47	20½	25.5	50	40
92											63	21	26.0	64	48½
93											34	19½	24.4	37	31
94											28	19	23.8	31	27
95											23	18½	23.3	26	23½
96											22	19	23.8	26	23½
97											21	18½	23.3	24½	22½
98											19	18½	23.3	23	21½
99											17	19	23.8	22	20½
100											20	19½	24.4	24½	22½
101											27	19	[illegible]	30	26
102											28	19	[illegible]	31	27
103											30	19½	24.4	33	28
104											44	20½	25.5	47½	38
105											48	20	24.9	50	40
106											115	21	26.0	106	73
107											800	23	28.2	500+	130+
108															
109															
110															
111															
112															
113															
114															
115															
116															
117															
118															
119															
120															

RIRIE DAM

Depth (feet)	BCC-86-7					BOC 86-7					BCC 86-8					BOC 86-8					Depth (feet)
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}	
1		13½	17.6			13	9	12.4	8	$8^{6.0}$		15½	19.9			15	15	19.3	16	$16^{12.0}$	1
2	23	13½	17.6	18	17½ $^{13.1}$	14	11½	15.3	11	$11^{8.3}$	22	17	21.6	23½	$22^{16.5}$	18	14	18.2	16½	16½ $^{12.4}$	2
3	40	14	18.2	29	25½ $^{19.1}$	15	10	13.5	9½	9½ $^{7.1}$	16	14½	18.8	16	$16^{12.0}$	17	13	17.0	14½	14½ $^{10.9}$	3
4	38	13	17.0	24	$22^{16.5}$	15	8	11.2	7½	7½ $^{5.6}$	14	14	18.2	14	$14^{10.5}$	45	18½	23.3	44	$36^{27.0}$	4
5	25	10½	14.1	14	$14^{10.5}$	10	12	15.9	10	$10^{7.5}$	13	13	17.0	12½	12½ $^{9.4}$	20	15½	19.9	20	$19^{14.3}$	5
6	25	12½	16.5	17½	$17^{12.8}$	10	11	14.7	9	$9^{6.8}$	26	16	20.4	27½	24½ $^{18.4}$	44	18½	23.3	43	$35^{26.3}$	6
7	19	11	14.7	13	$13^{9.8}$	12	13	17.0	12	$12^{9.0}$	44	17	21.6	40	$33^{24.8}$	42	17½	22.2	39½	32½ $^{24.4}$	7
8	10	9½	13.0	7½	7½ $^{5.6}$	14	12	15.9	12	$12^{9.0}$	48	18	22.7	45	36½ $^{27.4}$	29	16½	21.0	27½	24½ $^{18.4}$	8
9	18	13½	17.6	16	16	20	15	19.3	19	18½	37	14	18.2	27	24½	22	15½	19.9	21	20	9
10	19	15½	19.9	19	18½	15	16	20.4	17	16½	31	14½	18.8	25	23	37	18½	23.3	37½	31½	10
11	49	15	19.3	27	24½	13	16	20.4	15½	15½	16	12½	16.5	13½	13½	56	18½	23.3	52	43½	11
12	31	13½	17.6	22	20½	20	17	21.6	22	20½	16	12	15.9	13	13	35	17½	22.2	34	29	12
13	23	13	17.0	17½	17	19	16½	21.0	20½	19½	19	13½	17.6	16½	16½	28	15½	19.9	25½	23	13
14	17	13	17.0	14½	14½	17	16	20.4	18½	18	23	12½	16.5	17	16½	25	16	20.4	24½	22½	14
15	12	12½	16.5	11½	11½	20	17	21.6	22	20½	17	12½	16.5	14	14	18	14½	18.8	17½	17	15
16	10	10½	14.1	8½	8½	30	18	22.7	31	27	20	12½	16.5	15½	15½	13	12½	16.5	12	12	16
17	11	13	17.0	11½	11½	26	17½	22.2	27	24½	18	14	18.2	16½	16½	17	14½	18.8	16½	16½	17
18	13	14½	18.8	14	14	15	15	19.3	16	16	35	16	20.4	31	27	49	18	22.7	46	37	18
19	17	16½	21.0	19	18½	17	16	20.4	18½	18	40	15	19.3	31½	27½	38	19	23.8	39	32½	19
20	29	18	22.7	30	26	15	14	18.2	15	15	—	18	22.7	—	—	30	18	22.7	32½	28	20
21	30	18	22.7	31	27	26	16	20.4	24½	22½	92	20	24.9	84	60½	39	17½	22.2	33½	28½	21
22	27	17½	22.2	28	25	17	16	20.4	18½	18	105	20½	25.5	96	67½	35	18½	23.3	35½	30	22
23	24	17	21.6	25	23	20	16	20.4	20½	19½	—	20½	25.5	—	—	30	19	23.8	32½	28	23
24	41	20½	25.5	45	36½	27	17½	22.2	28	25	53	20½	25.5	55	43	29	19½	24.4	32	27½	24
25	38	20	24.9	41	33½	23	16½	21.0	23½	22	43	19½	24.4	44	36	30	17½	22.2	30	26	25
26	53	22	27.1	59	45½	29	17½	22.2	29½	25½	35	19½	24.4	37½	31½	28	17½	22.2	28½	25	26
27	65	23	28.2	73	54	37	19	23.8	38½	32	35	19½	24.4	38	31½	29	17½	22.2	29½	25½	27
28	64	22	27.1	69	51½	37	19	23.8	38½	32	38	19	23.8	39	32½	24	17	21.6	24½	22½	28
29	50	21	26.0	54	42½	35	18½	23.3	35½	30	38	17	21.6	35	29½	25	17	21.6	25½	23	29
30	20	18	22.7	23	21½	30	17½	22.2	30	26	24	14½	18.8	20½	19½	29	18	22.7	30	26	30
31	22	18	22.7	16½	16½	25	20½	25.5	30	26	13	15	19.3	14½	14½	56	19½	24.9	55	43	31
32	115	25½	31.9	190	125	56	21	26.0	59	45½	17	16	20.4	18½	18	35	18½	23.3	35½	30	32
33	72	23½	28.8	80	58	46	20½	25.5	49	39	26	14½	18.8	21½	20½	29	18	22.7	30	26	33
34	46	22	27.1	52	41	56	21½	26.6	61	47	14	14½	18.8	15	15	39	19	23.8	40	33	34
35	33	20½	25.5	37½	31½	55	22	27.1	61	47	11	15	19.3	13	13	25	17	21.6	25½	23	35
36	35	21	26.0	40	33	45	21½	26.6	51	40½	17	15	19.3	17	16½	23	16½	21.0	23½	22	36
37	29	22	27.1	36	30½	46	23½	28.8	56	43½	15	14	18.2	15	15	14	16	20.4	16	16	37
38	46	21	26.0	50	40	65	23½	28.8	74	54½	14	15	19.3	15	15	16	15	19.3	16½	16½	38
39	43	19½	24.4	44	36	37	20	24.9	41½	34	19	15	19.3	11½	11½	16	15½	19.9	17	16½	39
40	26	19	23.8	29	25½	31	20	24.9	35	29½	13	14½	18.8	14	14	11	14½	18.8	12½	12½	40

	BCC 86-7					BOC 86-7					BCC 86-8					BOC 86-8					DEPTH (FEET)
	N_B	BP	BP_C	N_{BC}	N_{60}	N_B	BP	BP_C	N_{BC}	N_{60}	N_B	BP	BP_C	N_{BC}	N_{60}	N_B	BP	BP_C	N_{BC}	N_{60}	
4	24	19½	24.4	28½	25	31	20	24.9	35	29½	14	15½	19.9	15½	15½	13	15	19.3	19½	19½	41
4	27	19½	24.4	31	27	30	19½	24.4	33	28	14	15	19.3	15	15	12	15½	19.9	14	14	
4	27	19	23.8	30	26	30	19	24.9	33	28	14	15½	19.9	15½	15½	13	15	19.3	14½	14½	
4	26	19	23.8	29	25½	26	18½	23.3	28½	25	16	16½	21.0	18	17½	15	15½	19.9	16½	16½	
4	23	19	23.8	26½	24	24	18	22.7	26½	24	24	17½	22.2	25½	23	16	16½	21.0	18	17½	
4	22	19½	24.4	26½	24	22	18	22.7	24½	22½	31	17½	22.2	31	27	24	16	20.4	23	21½	
4	23	20	24.9	32½	28	19	18	22.7	22	20½	28	17	21.6	28	25	33	17½	22.2	32½	28	
4	35	20½	25.5	40	33	25	19	23.8	28½	25	24	14½	18.8	20½	19½	45	19½	24.4	46	37	
4	31	21½	26.6	37	31	24	19	23.8	27½	24½	19	13	17.0	15½	15½	40	18½	23.3	40	33	
6	36	22	27.1	43	35	27	19	23.8	30	26	15	15½	19.9	16½	16½	26	17	21.6	26½	24	50
5	37	22	27.1	43½	35½	30	20	24.9	34	29	16	16½	21.0	18	17½	21	16½	21.0	22	20½	
5	36	22	27.1	43	35	23	19½	24.4	27½	24½	19	17	21.6	21	20	19	16½	21.0	20½	19½	
5	37	23½	28.8	46	37	28	19½	24.4	32	27½	21	17½	22.2	23½	22	27	16½	21.0	26	23½	
6	51	24½	29.9	63	48	40	21½	26.6	46	37	25	19	23.8	28½	25	55	19	23.8	53	41½	
5	77	24	29.3	86	62	69	[illegible]	28.2	76	56	45	20½	25.5	48	38½	65	20	24.9	65	49	
5	80	23½	28.8	88	63	70	23½	28.8	79	57½	62	21	26.0	64	48½	66	19½	24.4	65	49	
6	71	22	27.1	75	55	75	23	28.2	84	60½	76	21	26.0	76	56	65	19½	24.4	64	48	
5	62	21½	26.6	65	49	88	23	28.2	93	66	80	21	26.0	79	57½	60	19½	24.4	60	46	
5	44	22½	27.7	52	41	89	22½	27.7	93	66	90	21	26.0	86	62	53	19	23.8	51	40½	
6	59	24	29.3	70	52	108	23	28.2	113	78	116	21½	26.6	110	76	44	18½	23.3	43	35	60
6	150	24	29.3	156	103	110	23	28.2	115	79	143	22½	27.7	140	94	47	18½	23.3	45	36½	
6	143	24½	29.9	155	103	100	22½	27.7	102	71	208	22½	27.7	190	125	68	20	24.9	65	49	
6	110	23½	28.8	118	80	60	21	26.0	63	48	460	23	28.2	400+	130+	95	21	26.0	90	64	
6	70	22	27.1	75	55	50	22	27.1	56	43½	780	22	27.1	500+	130+	133	22	27.1	127	86	
6	59	23	28.2	67	50½	50	21½	26.6	55	43	600	23½	28.8	500+	130+	140	21½	26.6	128	86	
6	46	23	28.2	55	43	45	20½	25.5	48	38½	350	20½	25.5	250	130+	240	22	27.1	210	130+	
6	56	23½	28.8	65	49	44	22	27.1	50½	40	280	24	29.3	270	130+	200	22	27.1	190	125	
6	61	22	27.1	66	50	55	22	27.1	61	47	184	22½	27.7	170	113	170	21½	26.6	150	100	
6	81	23	28.2	87	62½	39	21	26.0	44	36	150	23	28.2	148	99	130	22	27.1	125	85	
7	115	24½	29.9	125	85	14	19	23.8	19	18½	122	23	28.2	125	85	80	22	27.1	83	60	70
7	115	24	29.3	123	84	35	22½	27.7	42½	35	180	23½	28.8	180	119	95	21½	26.6	94	66½	
7	123	24	29.3	132	89	58	21½	26.6	62½	47½	192	23½	28.8	190	125	170	22½	27.7	160	107	
7	120	24½	29.9	132	89	60	22	27.1	65	49	128	23½	28.8	135	91	117	22	27.1	114	79	
7	120	24½	29.9	132	89	75	23	28.2	82	59½	75	21½	26.6	77	56½	80	20	24.9	75	55	
7	108	24½	29.9	120	82	95	23½	28.8	103	72	45	20	24.9	47	38	30	16½	21.0	28½	25	
7	94	24	29.3	102	71	84	23	28.2	90	64	23	18½	23.3	26	23½	30	16	21.0	28½	25	
7	84	24	29.3	95	67	75	23	28.2	82	59½	17	17½	22.2	20	19	15	15½	19.9	16½	16½	
7	98	23	28.2	103	72	60	21½	26.6	64	48½	16	17	21.6	19	18½	15	16½	21.0	17½	17	
7	107	23½	28.8	114	79	40	20	24.9	42½	35	14	17½	22.2	18	17½	11	16½	21.0	14	14	
8	121	23	28.2	123	84	40	21½	26.6	46	37	14	18	22.7	19	18½	8	16½	21.0	11½	11½	80

Depth (feet)	BCC 86-7 N_B	BCC 86-7 BP	BCC 86-7 BP_c	BCC 86-7 N_{BC}	BCC 86-7 N_{60}	BOC 86-7 N_B	BOC 86-7 BP	BOC 86-7 BP_c	BOC 86-7 N_{BC}	BOC 86-7 N_{60}
81	142	24½	29.9	152	101	85	22½	27.7	90	64
82	205	24½	29.9	200	130	80	23½	28.8	88	63
83	290	24	29.3	270	130+	88	24	29.3	98	69
84	310	24½	29.9	300	130+	93	24	29.3	102	71
85	250	24½	29.9	250	130+	120	24½	29.9	130	83
86	255	25	30.4	260	130+	119	24	29.3	128	87
87	288	25	30.4	290	130+	110	24	29.3	120	82
88	214	24	29.3	212	130+	115	24½	29.9	125	85
89	138	23	28.2	140	94	103	23½	28.8	110	76
90	121	23	28.2	125	85	95	23	28.2	100	76
91	145	23	28.2	145	97	87	23	28.2	92	65½
92	185	23	28.2	175	116	73	23	28.2	80	58
93	183	24	29.3	185	122	100	23½	28.8	110	76
94	203	25	30.4	213	130+	104	23	28.2	110	76
95	170	24½	29.9	180	119	90	23½	28.8	98	69
96	195	24	29.3	195	128	84	23	28.2	90	64
97	200	24	29.3	200	130	74	23	28.2	81	59
98						90	23½	28.8	98	69
99										
100										
101										
102										
103										
104										
105										
106										
107										
108										
109										
110										
111										
112										
113										
114										
115										
116										
117										
118										
119										
120										

Depth (feet)	BCC 86-8 N_B	BCC 86-8 BP	BCC 86-8 BP_c	BCC 86-8 N_{BC}	BCC 86-8 N_{60}	BOC 86-8 N_B	BOC 86-8 BP	BOC 86-8 BP_c	BOC 86-8 N_{BC}	BOC 86-8 N_{60}
81	12	18	22.7	15½	15½	10	16	20.4	13	13
82	13	18	22.7	17½	17	8	16	20.4	11	11
83	13	17½	22.2	17	16½	25	20	24.9	30	26
84	13	17	21.6	16½	16½	22	19	23.8	26	23½
85	13	16½	21.0	16	16	14	17½	22.2	18½	18
86	13	16½	21.0	16	16	12	17	21.6	15½	15½
87	13	18½	23.3	17½	17	10	17½	22.2	14	14
88	22	20	24.9	27	24½	11	17	21.6	14½	14½
89	90	21½	26.6	90	64	28	19	23.8	31	27
90	1000+	24	29.3	800+	130+	63	20	24.9	64	48½
91						73	20½	25.5	72	53½
92						37	18	22.7	36	30½
93						29	18½	23.3	31	27
94						30	19	23.8	32½	28
95						22	17½	22.2	24	22
96						18	17½	22.2	21	20
97						14	17½	22.2	17½	17
98						15	17	21.6	18	17½
99						20	18	22.7	23	21½
100						23	18	22.7	25	23
101						34	17½	22.2	33	28
102						36	17½	22.2	34	29
103						29	17½	22.2	29½	25½
104						52	19	23.8	50	40
105						1100+	21½	26.6	700+	130+
106										
107										
108										
109										
110										
111										
112										
113										
114										
115										
116										
117										
118										
119										
120										

RIRIE DAM

DEPTH (feet)	BCC 86-9					BOC 86-9				
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}
1							14	18.2		
2		12	15.9			7	14	18.2	9½	7.1 9½
3	15	14	18.2	15	11.3 15	19	13	17.0	15½	11.6 15½
4	20	14½	18.8	18½	13.5 18	13	12	15.9	11½	8.6 11½
5	20	14	18.2	17½	12.9 17	13	16	20.4	15½	16.6 15½
6	26	15½	19.9	23½	16.5 22	21	17	21.6	22½	15.8 21
7	25	16½	21.0	24½	18.9 22½	21	16	20.4	21	15.0 20
8	28	17	21.6	28	18.8 25	33	17	21.6	31½	20.6 27½
9	35	18	22.7	35	29½	38	19½	24.4	40	33
10	34	19	23.8	36	30½	25	17½	22.2	26½	24
11	58	19	23.8	55	43	23	16	20.4	22½	21
12	84	19½	24.4	75	55	36	18½	23.3	36½	30½
13	62	21	26.0	64	48½	27	18	22.7	29	25½
14	57	20	24.9	57	44	30	18½	23.3	32	27½
15	38	18½	23.3	38½	32	24	17	21.6	25	23
16	41	18	22.7	40	33	25	17	21.6	25½	23
17	29	16½	21.0	27½	24½	32	18	22.7	32½	28
18	33	17	21.6	31½	27½	40	18½	23.3	40	33
19	38	18½	23.3	38½	32	35	19	23.8	37	31
20	32	18	22.7	33	28	35	19½	24.4	37½	31½
21	23	17½	22.2	24½	22½	50	20½	25.5	53	41½
22	26	17	21.6	26½	24	40	18½	23.3	40	33
23	56	20	24.9	56	43½	37	18	22.7	36½	30½
24	148	23	28.2	146	97	60	20	24.9	60	46
25	115	22½	27.7	117	80	58	20½	25.5	60	46
26	94	21	26.0	90	64	53	20	24.9	54	42½
27	95	20½	25.5	89	63½	60	20	24.9	60	46
28	100	20½	25.5	92	65½	70	21½	26.6	73	54
29	81	21	26.0	80	58	45	20½	25.5	48	38½
30	113	21½	26.6	108	74	25	18½	23.3	28	25
31	178	23	28.2	170	113	35	19½	24.4	37½	31½
32	178	23	28.2	170	113	45	18½	23.3	43	35
33	110	21	26.0	102	71	29	18	22.7	28	25
34	105	21	26.0	98	69	45	19	23.8	44½	36
35	108	21	26.0	107	71	56	20½	25.5	57	44
36	130	21	26.0	115	79	70	20½	25.5	70	52
37	112	21	26.0	103	73	40	19	23.8	41	33½
38	76	20	24.9	72	53½	32	18	22.7	32½	28
39	56	19½	24.4	55	43	40	19	23.8	41	33½
40	66	20½	25.5	66	50	39	18	22.7	38	31½

	BCC 86-9					BOC 86-9							DEPTH (feet)
	N_B	BP	BP_c	N_{BC}	N_{60}	N_B	BP	BP_c	N_{BC}	N_{60}			
4	57	20	24.9	57	44	43	18	22.7	41	33½			41
4	69	20	24.9	66	50	42	17½	22.2	40	33			
4	59	20	24.9	58	45	33	19	23.8	35	29½			
4	63	20	24.9	62	47½	42	14	18.2	30	26			
4	79	20½	25.5	76	56	60	17	21.6	51	40½			
4	88	21	26.0	85	61	58	19½	24.4	57	44			
4	04	21½	26.6	102	71	83	20½	25.5	80	58			
4	139	21½	26.6	127	86	63	20½	25.5	64	48½			
4	–	20½	25.5			56	20	24.9	56	43½			
5	43	19½	24.4	44	36	43	19	23.8	43	35			450
5	32	19	23.8	34	29	22	17	21.6	23½	22			
5	39	19½	24.4	41	33½	17	18½	23.3	21	20			
5	39	20	24.9	42	34½	27	17	21.6	27	24½			
5	48	20	24.9	50	40	20	15	19.3	19	18½			
5	54	21	26.0	57	44	15	16	20.4	17	16½			
5	59	21	26.0	61	47	10	16	20.4	13	13			
5	54	21	26.0	57	44	13	16½	21.0	16	16			
5	[illegible]2	21	26.0	64	48½	15	15½	19.9	16½	16½			
5	63	21½	26.6	66	50	19	17½	22.2	21½	20			
6	55	21	26.0	58	45	21	19	23.8	25	23			60
6	47	20½	25.5	52	41	40	17½	22.2	38	31½			
6	29	20	24.9	33	28	15	16½	21.0	17½	17			
6	39	21½	26.6	45	36½	10	16½	21.0	13	13			
6	118	22½	27.7	118	80	12	18½	23.3	16½	16½			
6	294	24½	29.9	280	130+	16	18½	23.3	21	20			
6	235	23½	28.8	225	130+	20	18	22.7	23½	22			
6	232	24	29.3	230	130+	45	21	26.0	49	39			
6	102	23	28.2	107	75	230	22½	27.7	205	130+			
6	102	24	29.3	110	76								
7													70
7													
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7													
8													80

APPENDIX I: RESULTS OF SURFACE SEISMIC GEOPHYSICAL TESTS PERFORMED BY WES

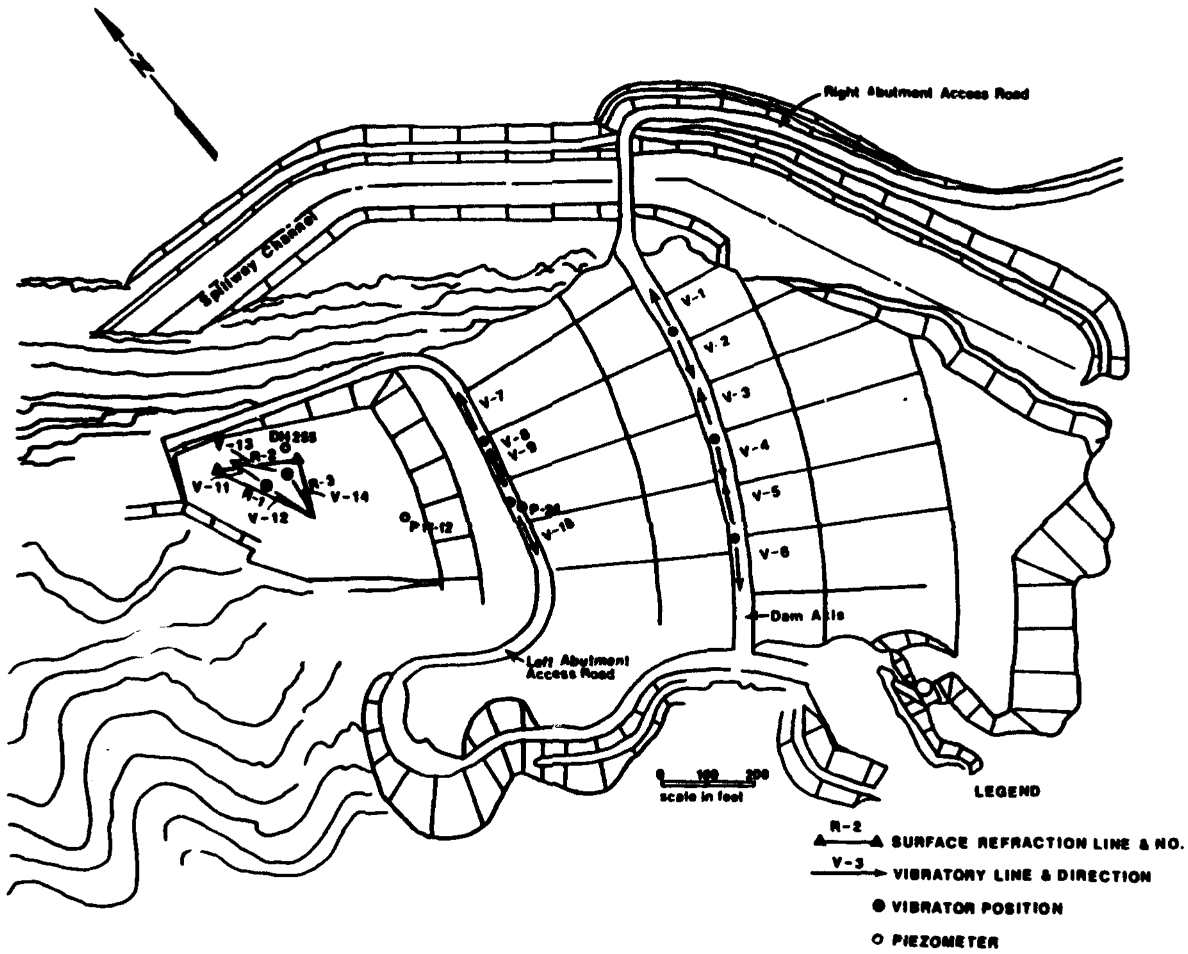


Figure I1. Locations of surface geophysical measurements made by WES

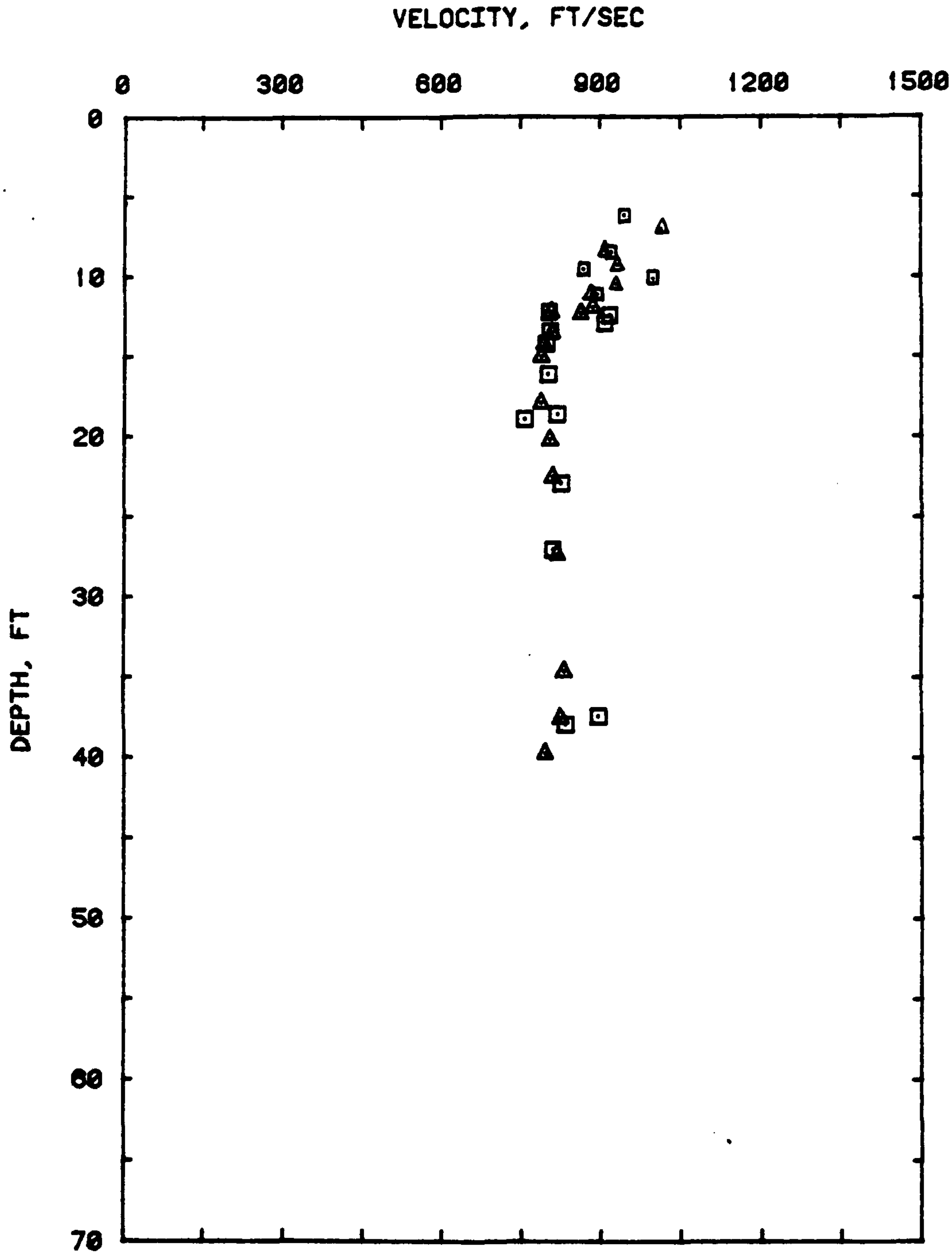


Figure I2. Profile of Rayleigh wave velocities for lines V-1 and V-2

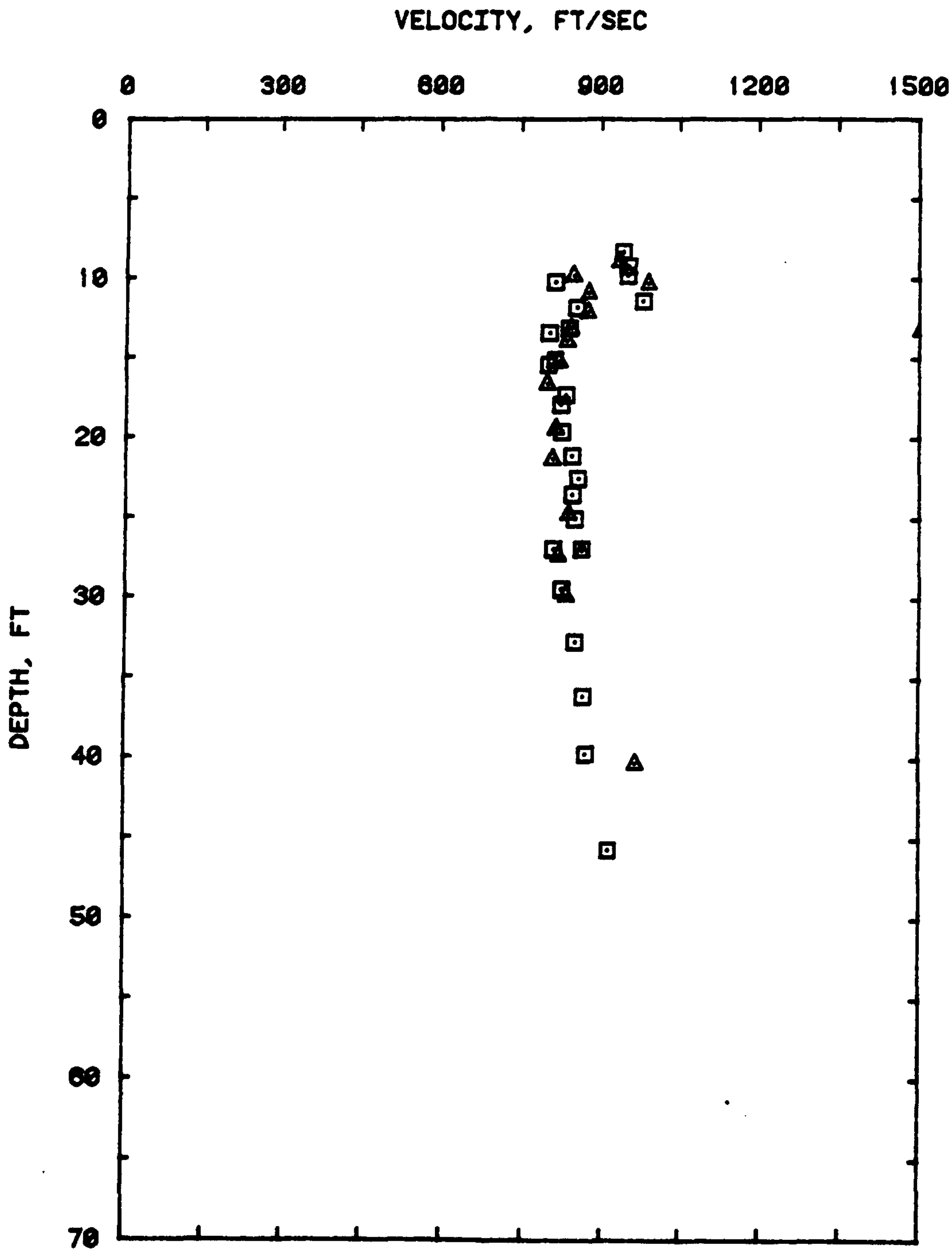


Figure I3. Profile of Rayleigh wave velocities for lines V-3 and V-4

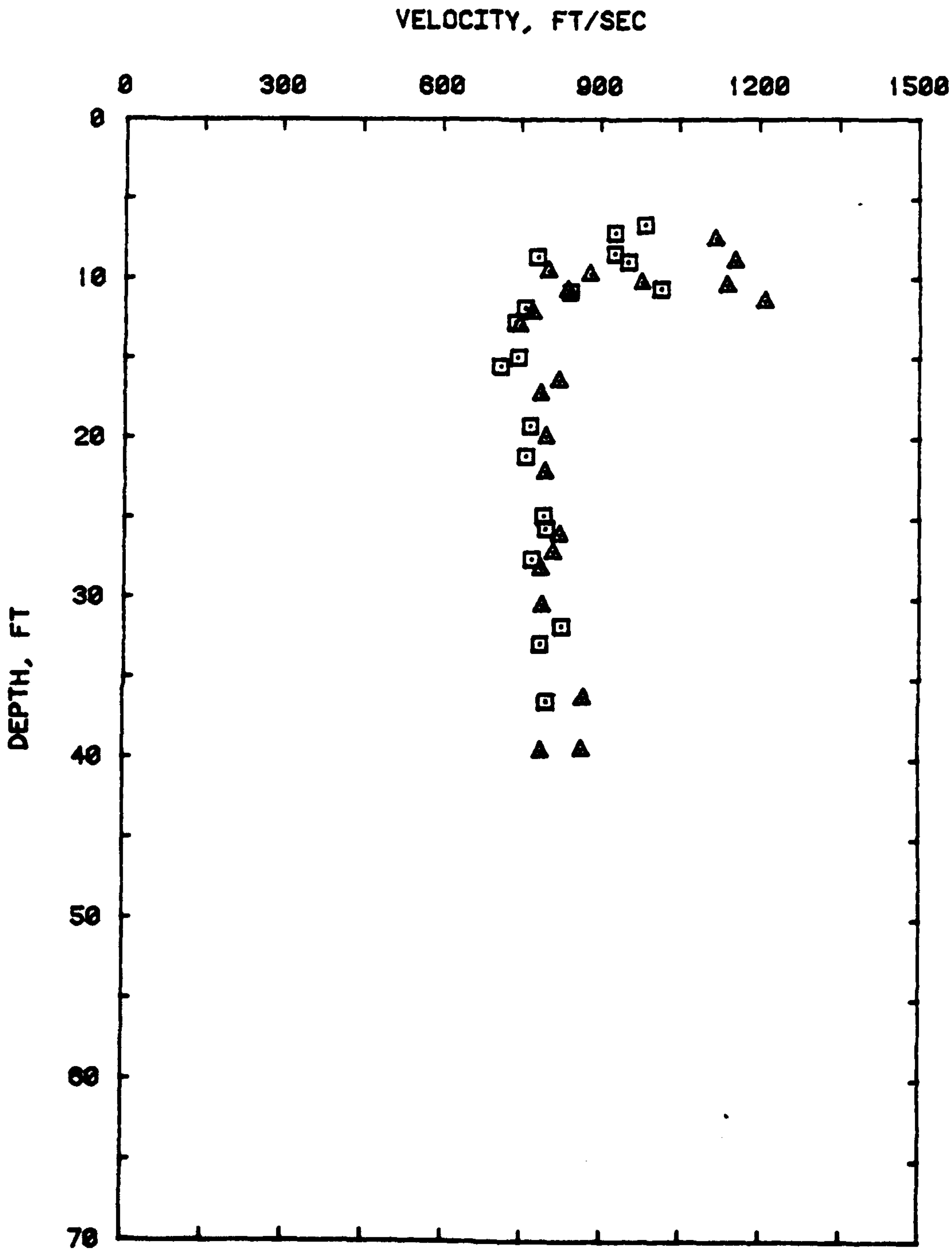


Figure I4. Profile of Rayleigh wave velocities for lines V-5 and V-6

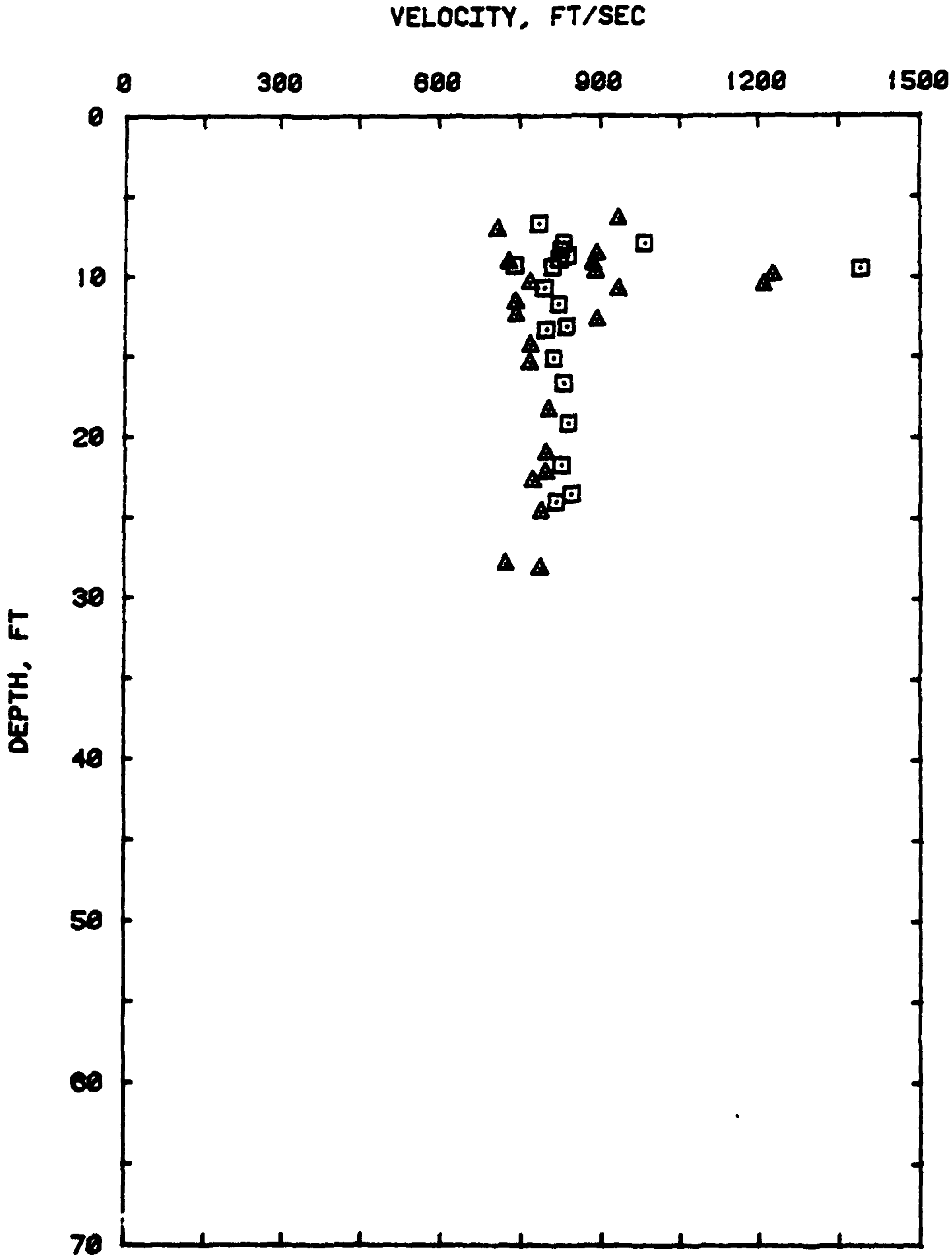


Figure I5. Profile of Rayleigh wave velocities for lines V-7 and V-8

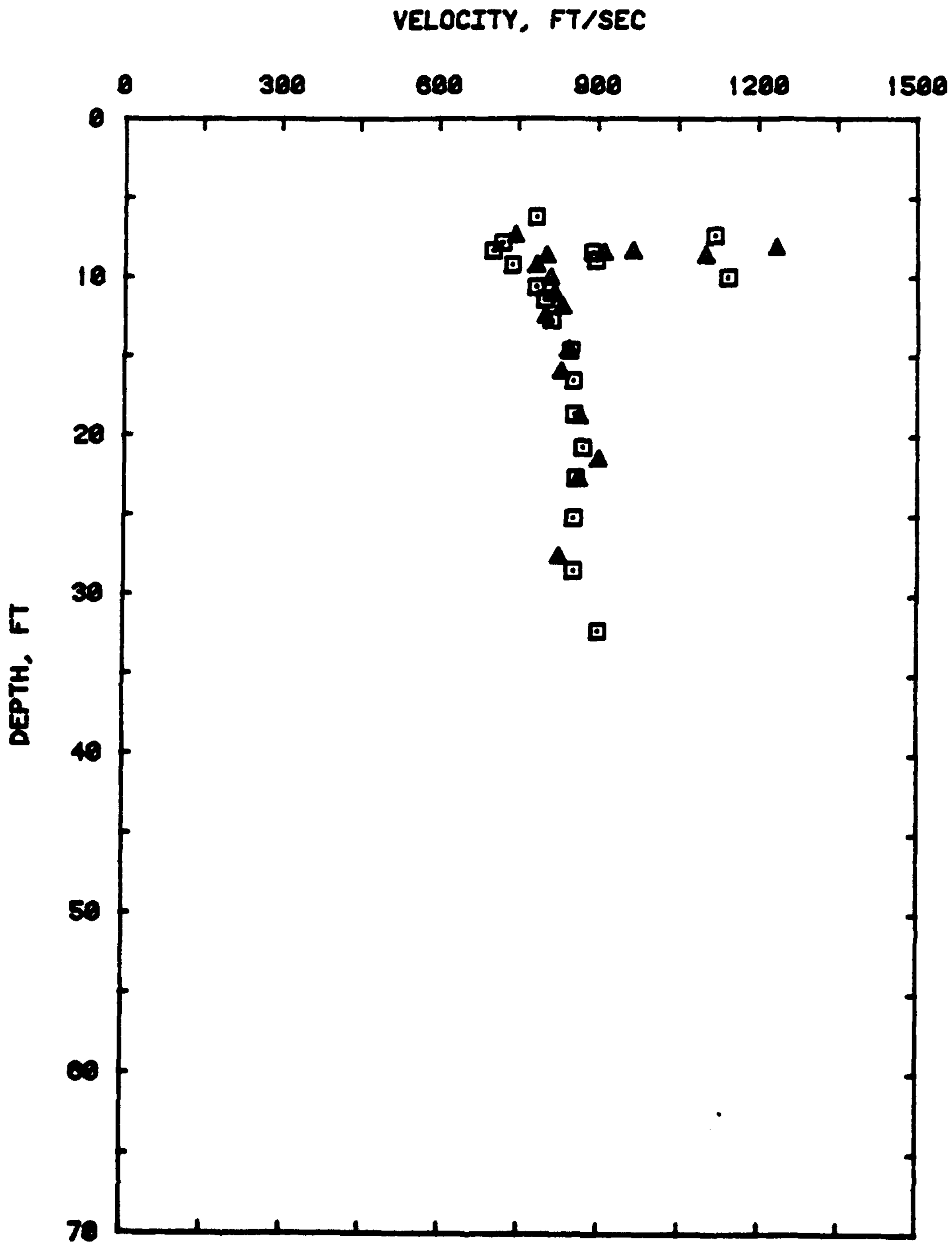


Figure I6. Profile of Rayleigh wave velocities for lines V-9 and V-10

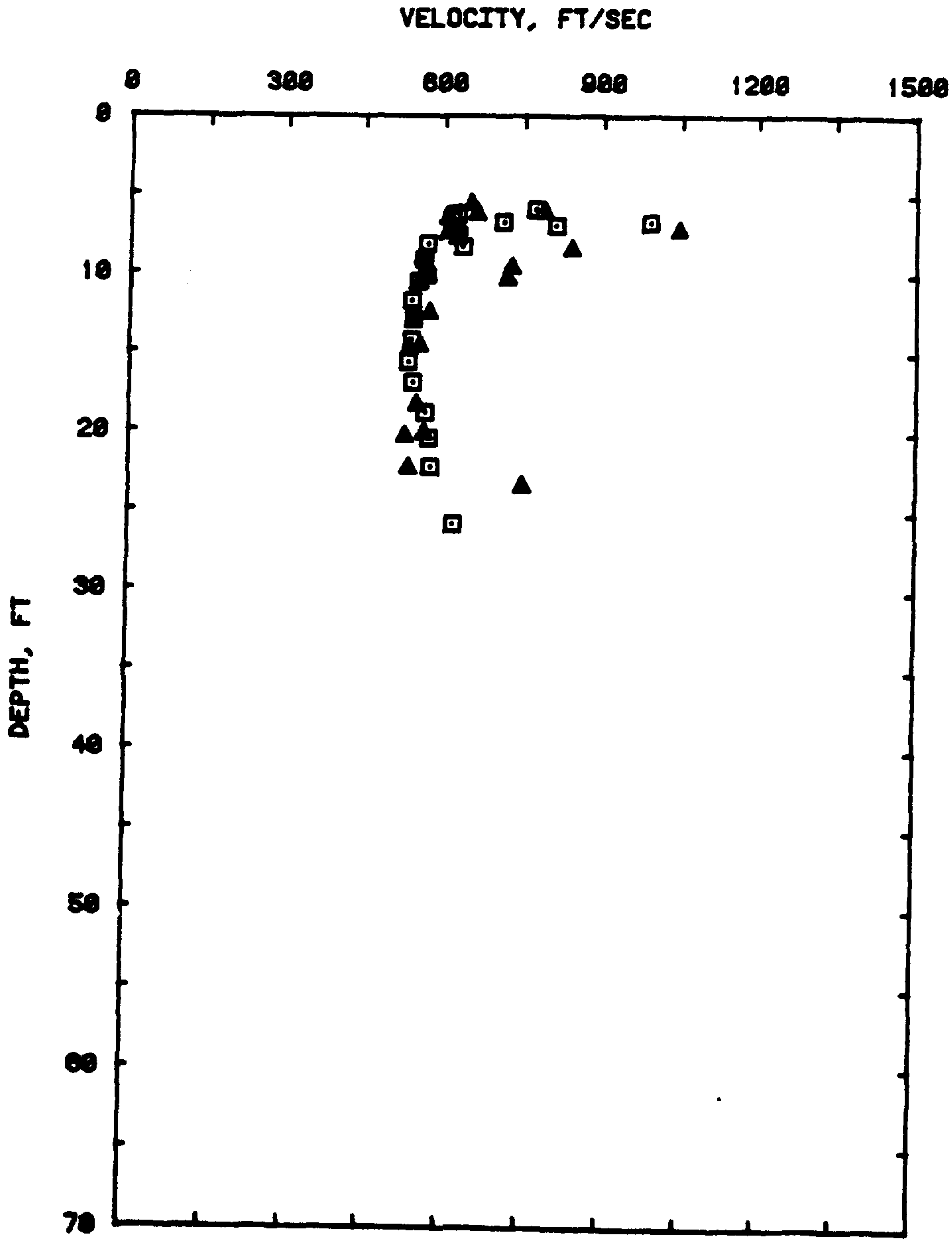


Figure I7. Profile of Rayleigh wave velocities for lines V-11 and V-12

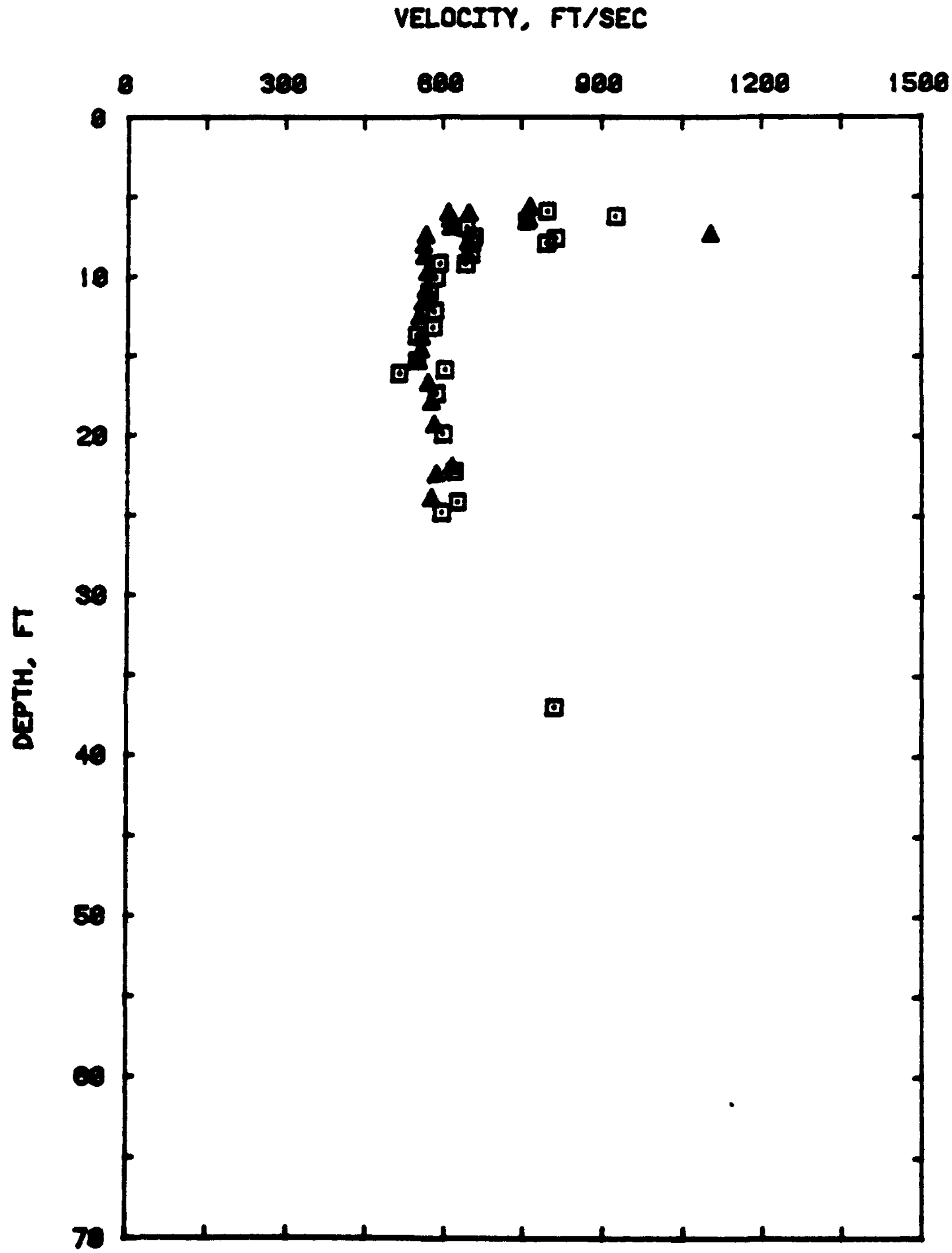
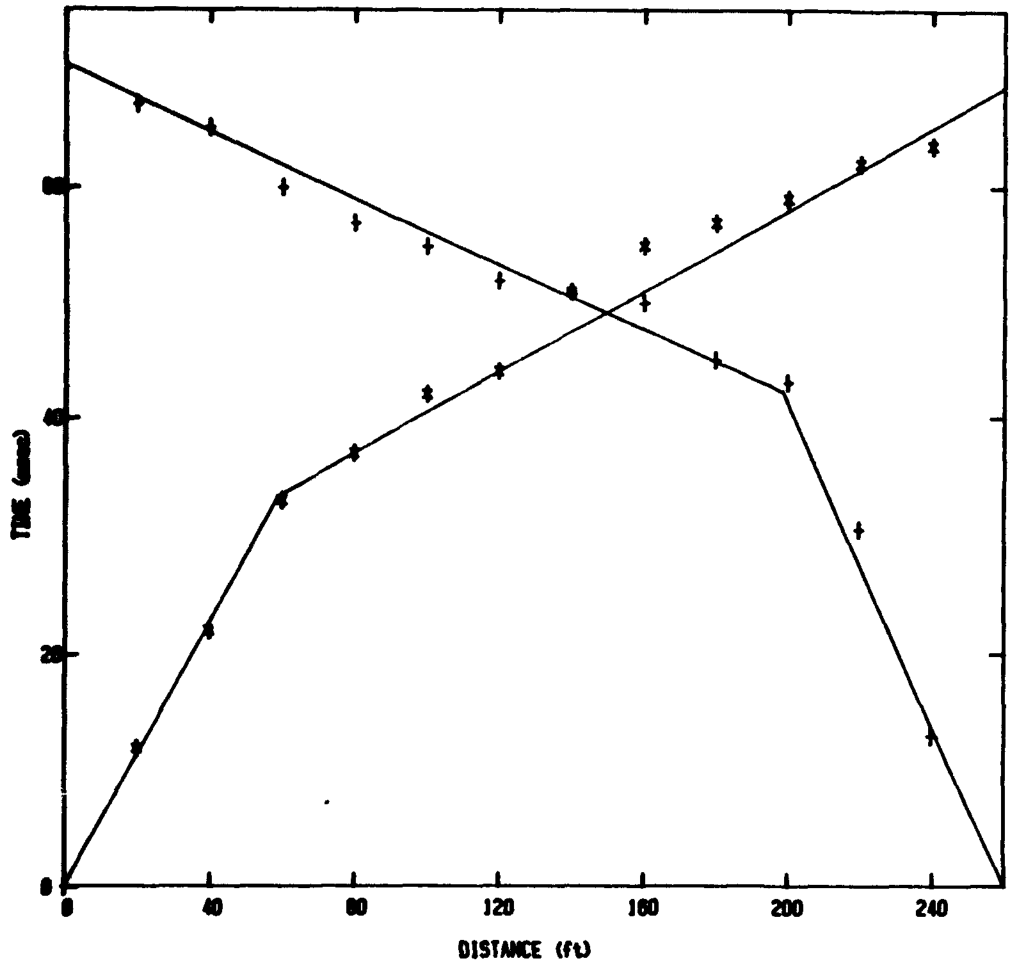


Figure I8. Profile of Rayleigh wave velocities for lines V-13 and V-14



RIRIE DAM SPREAD 1

**** INPUT DATA ****

layer #	forward vel ft/s	forward ti msec	reverse vel ft/s	reverse ti msec
1	1774	0	1462	0
2	5718	23	7058	33.5

**** COMPUTED PROFILE ****

Ground Surface

1820

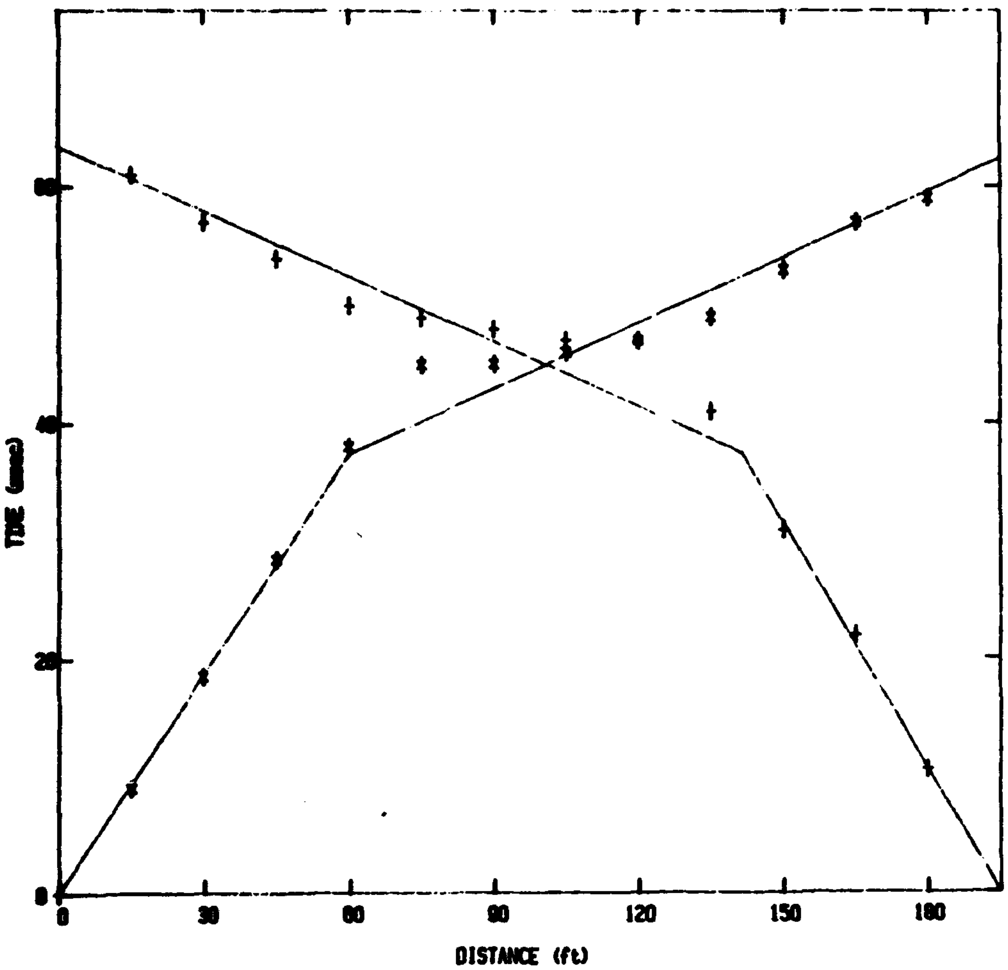
18.5 ———————— 28

6320

This layer extends to unknown depth

NOTE: All depths in ft
All velocities in ft/s

Figure I9. Time-distance plots for surface refraction line no. 1



RIRIE DAM SPREAD 2

****** INPUT DATA ******

layer #	forward vel ft/s	forward ti msec	reverse vel ft/s	reverse ti msec
1	1613	0	1428	0
2	5408	28.9	5454	27.7

****** COMPUTED PROFILE ******

Ground Surface

1520

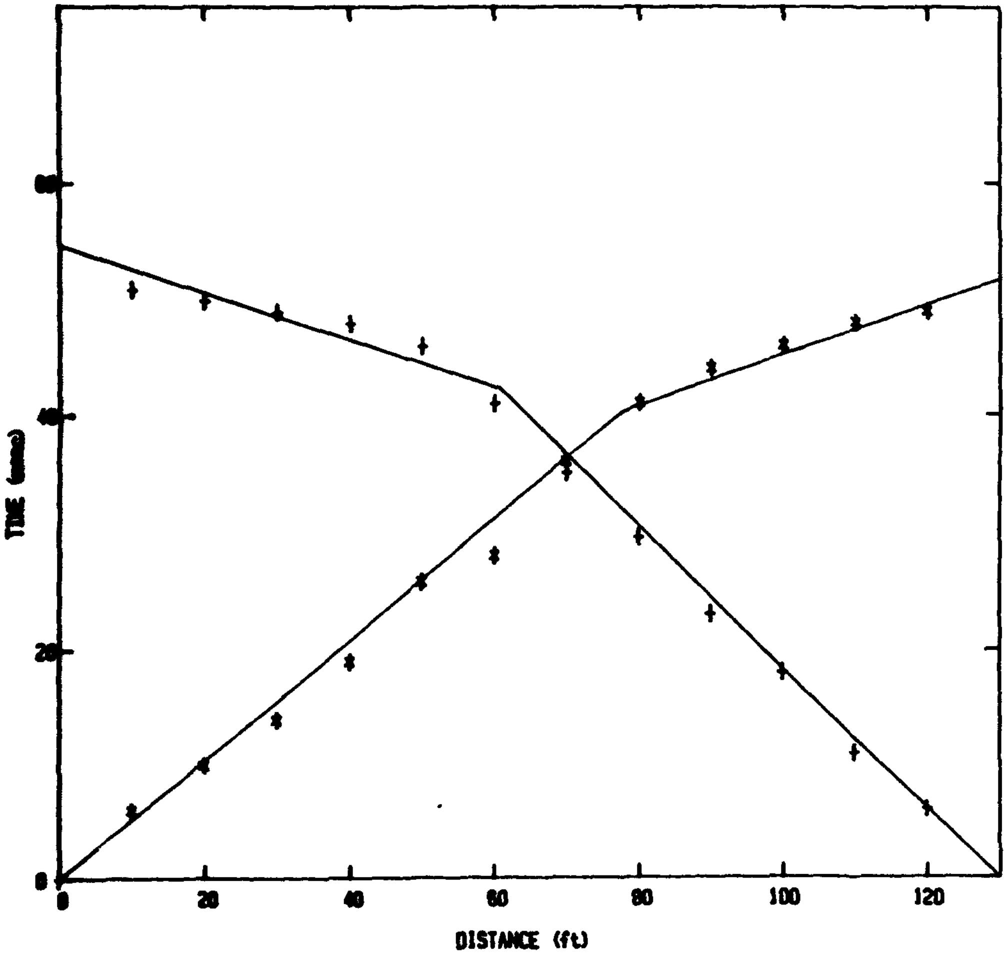
21 — 22

5430

This layer extends to unknown depth

NOTE: All depths in ft
All velocities in ft/s

Figure I10. Time-distance plots for surface refraction line no. 2



RIRIE DAM SPREAD 3

**** INPUT DATA ****

layer #	forward vel ft/s	forward ti msec	reverse vel ft/s	reverse ti msec
1	1929	0	1640	0
2	4545	23.2	4650	28

**** COMPUTED PROFILE ****

Ground Surface

22.5 —— 1780 / 4690 —— 27

This layer extends to unknown depth

NOTE: All depths in ft
All velocities in ft/s

Figure I11. Time-distance plots for surface refraction line no. 3

APPENDIX J: REPORT SUBMITTED BY DAVENPORT/HADLEY, LTD.

(January 1987)

INTRODUCTION

Downhole and cross-hole shear and compressional wave surveys were conducted within the downstream embankment and foundation materials of Ririe Dam. The dam is located approximately four miles southwest of Ririe, Idaho. Ririe dam is a zoned earthfill structure founded on alluvium and basalt bedrock. The dam is approximately 180 feet high and has a crest length of approximately 3,600 feet.

The original downhole survey was completed to a depth of 185 feet and the crosshole survey was completed to a depth of 135 feet. The original field work was conducted between September 8 and 16, 1986 by Davenport/Hadley, Ltd. personnel. A second downhole survey was completed to a depth of 250 feet during work conducted December 11 and 12, 1986. The data were collected at five-foot depth intervals in order to obtain shear and compressional wave velocities for the computation of Poisson's ratio and for comparison with drilling information.

SUMMARY

The logs of the two drill holes used in the downhole surveys are substantially different both in the amount of detail and in the types of materials encountered.

The results of the initial downhole survey (DH-260) and the accompanying cross-hole survey correlate well with each other. However, the results do not correlate particularly well with the drill logs currently available. Both surveys indicate four layers witnin the depth investigated. Layer 1 extends from 0 to 18 feet and exhibits velocities typical of near surface soil (or fill) materials. Layer 2 extends from

18 to about 50 feet and exhibits slightly higher velocities typical of denser soil (or fill) materials. Layer 3 extends from about 50 to about 95 feet and exhibits velocities typical of moderately dense to very dense soils. This layer appears to correspond with the alluvium shown on the drill logs. Layer 4 extends from 95 to 135 feet (185 feet on the downhole survey) and shows a distinct increase in both shear and compressional wave velocities over Layer 3. From 95 to 125 feet, Layer 4 exhibits velocities representative of weathered and/or fractured basalt. Below 125 feet, the velocities increase to values more representative of sound basalt bedrock.

The results of the second downhole survey (DH-261A) correlate well with the available drill log. This survey indicates six different layers. Layer 1 extends from 0 to 10 feet and exhibits velocities typical of fill material. Layer 2 extends from 10 to 34 feet and exhibits velocities representative of the basalt rubble. Layer 3 extends from 34 to 60 feet, and exhibits velocities that are considered to be representative of saturated basalt rubble. Layer 4 extends from 60 to 132 feet, and exhibits an increase in velocities, which correlates with a basalt flow. Layer 5 extends from 132 to 212 feet, and exhibits a decrease in velocity which appears to correlate with the upper portion of the tuffaceous sediments. The deepest layer encountered, Layer 6, extends from 212 to 250 feet (the total depth of the drill hole), and shows a marked increase in velocity, even though the drill log indicates undifferentiated tuffaceous sediments through the entire interval from 132 to 252 feet.

Table I is a summary of the compressional wave velocity (V_p), shear wave velocity (V_s) and Poisson's Ratio (u) for the different site materials. The velocity ranges incorporate data from both downhole surveys and the cross-hole survey. The material descriptions used in this report are those obtained from the available drill logs.

TABLE I
SUMMARY RESULTS OF GEOPHYSICAL SURVEYS

Material	V_p	V_s	u
Fill	1,600-2,550	780-1,100	0.344-0.386
Alluvium	4,400	1,650-2,000	0.370-0.418
Basalt Rubble	2,400-5,000	1,100-2,200	0.367-0.380
Basalt Flow	8,400	2,650	0.445
Tuff. Seds.	5,650-10,400	1,600-2,480	0.456-0.470
Rock	9,800-12,500	3,600-5,500	0.380-0.422

FIELD PROCEDURE

The original scope of work issued by the U.S. Army Corps of Engineers called for the determination of compressional and shear wave velocities to a depth of 250 feet by cross-hole and downhole surveying techniques. Due to difficulties in drilling, the initial set of three drill holes could only be completed to total depths of 216 feet in one hole (DH-260) and 136 feet and 137 feet for the remaining two holes. The three original boreholes were located approximately 20 feet downstream of the road on the toe berm as shown on Figure 1. The holes were approximately 12 feet apart at the surface and had been cased with 4-inch diameter PVC pipe. The annular space was grouted to obtain good contact between the casing and the surrounding material. The Corps' technical representative (Mr. David Sykora) determined that downhole surveying would be done to a depth of 185 feet in the deep hole (DH-260) and cross-hole surveying would be performed to a depth of 135 feet. It was also determined at that time to amend the program to include the drilling of a fourth hole to a depth of 250 feet in order to conduct a downhole survey to the original specified depth (250 feet).

After the initial cross-hole and downhole surveying was completed in September, another drill hole was completed to a depth of 252 feet in early December. This drill hole is approximately 150 feet south-southwest of the drill holes used for the original cross-hole and downhole surveying. This new drill hole was marked as DH-261 in the field and on the driller's log forwarded to Davenport/Hadley. However, one of the drill holes used in the cross-hole surveying had also been designated DH-261, therefore the new drill hole (with a TD of 252 feet) has hereafter been designated as DH 261A.

ASTM-4428 (Standard Test Methods for Crosshole Seismic Testing) was used as a guide for conducting the cross-hole survey. An ABEM Terraloc 24-channel, signal enhancement seismograph was used to record all the data. Both printed records and digital cassette tapes were obtained for the original downhole and cross-hole survey. Printed records only were obtained for the downhole survey performed in DH 261A.

Downhole Survey

For the downhole testing, a GeoSpace HS-J-LP3D three component, triaxial geophone was lowered into the drill hole to the desired recording depth. To produce shear wave energy, a sledgehammer was impacted horizontally on the end of a timber kept in contact with the ground by the weight of a vehicle. Opposite ends of the timber were impacted to produce a reversal in the shear wave energy (and in the resulting shear wave arrivals on the records). The horizontal elements in the geophone were used to record the shear wave arrivals. To produce compressional wave energy, the sledgehammer was impacted vertically on a steel plate located the same distance from the borehole as the timber. The vertical element in the triaxial geophone was used to record the compressional wave arrivals. An example of a downhole

record is shown on Figure 2.

The driller's log of DH 261A indicated that an excessive amount of grout was used between the ground surface and 55 feet depth in the hole. In order to investigate the possible effects of the grouted area on the downhole survey, compressional wave data was recorded at 25 foot intervals in the drill hole, using a long source-to-hole collar offset. The resulting data is consistent with the compressional wave data recorded from the close source-to-hole collar interval used in both the original and subsequent downhole survey. This indicates that the grout zone had little effect on the compressional and shear wave velocities between the depths of 55 and 250 feet.

Cross-Hole Survey

The cross-hole survey was conducted by lowering a GeoSpace HS-J-LP3D triaxial geophone into each of the two receiver holes (Boreholes 261 and 262) to the testing depth. Both geophones were secured at this depth by inflating a rubber packer which locked each geophone to the side of the borehole. A Bison Model 1465 downhole shear wave hammer was lowered into the source hole (Borehole 260) to the same depth as the recording geophones and locked into the borehole by a hydraulically operated shoe. A vertical slide weight attached to the downhole shear wave hammer was used to produce vertically polarized shear wave energy. The impact direction of the slide weight was reversed in order to obtain a reversal in the shear wave arrivals on the records to aid in the identification of the shear wave. Due to the impact direction of the slide weight (up and down), the vertical elements in each receiver geophone were used to record the shear wave energy, and the horizontal elements were used to record the compressional wave energy. Examples of the cross-hole records are shown on Figures 5 (for soil) and 6 (for rock). Typically, compressional wave energy generated

by the shear wave hammer is very weak. At a depth of 25 feet in DH-260, the casing was compressed to the point that the slide weight on the downhole hammer would not function properly. For this reason, no data was recorded at this depth.

A drift survey was conducted by Nuclear Logging, Inc. of Denver to determine the true distance between the boreholes at ten-foot depth intervals. Straight line distances between the five-foot intervals were interpolated. Dividing these true distances by the corresponding arrival times yields shear and compressional wave velocities for each depth interval.

INTERPRETATION

Downhole Surveys

In the downhole surveys, the compressional wave arrivals were recorded on the vertical element of the geophone, and the shear wave arrivals were recorded on the horizontal elements of the geophone. The arrival times for each wave type were picked based on wave character, amplitude and frequency content. Since the impact point on the surface is located a short distance away from the collar of the drill hole, the near-surface arrival times must be corrected to vertical times using simple geometric corrections. The corrected times are plotted versus the geophone depth to produce a time-distance graph (Figures 3 and 4). The slopes of the various line segments represent the shear and compressional wave velocities, and the breaks in slope indicate layer boundaries. Poisson's ratio has been calculated for each layer using the following formula:

$$u = (1-2R^2)/(2-2R^2)$$

where u = Poisson's ratio

R = velocity ratio V_s/V_p

V_p = compressional wave velocity

V_s = shear wave velocity

Cross-Hole Survey

The cross-hole survey records the shear wave arrivals on the vertical elements and the compressional wave arrivals on the horizontal elements of the borehole geophones. The arrivals are assumed to be for direct, horizontal paths between the source hole and the two receiver holes. By having two receiver holes, three values of shear and compressional wave velocity can be computed at each depth (source to Receiver Hole 1, source to Receiver Hole 2 and Receiver Hole 1 to Receiver Hole 2). The three values provide a system of checks to increase confidence in the data and to check for refracted arrivals.

Sources of Error

Variations in the computed velocities arise from many sources. The largest error usually occurs in the interpreter's judgement in selecting the proper arrival times. In addition to this obvious source of error, there are numerous other errors associated with the timing and system parameters. Due to the location of the trigger on the downhole hammer, a time difference of about 0.25 millisecond results between the up and down hammer blows. The orientation and response time of the geophone elements in the receiver holes can also cause timing errors. Because the distances between the source and receiver holes are so small relative to the velocities, the timing becomes extremely critical. For example, at 10 feet away in a material with a velocity of 10,000 feet per second, the travel time is 1 millisecond. With a timing error of +/- 0.25 milliseconds, the calculated

velocity could range from 8,000 to 10,256 feet per second (fps). Thus, the calculated velocities and resulting Poisson's ratios must be used with discretion.

RESULTS

The results of the downhole surveys are presented on Figures 3 and 4. The results of the cross-hole surveys are presented on Figures 7 through 10. Since the logs of the two holes used for the downhole surveys are so different, and because the results of the two downhole surveys yielded different results, the discussion of the results has been broken into two separate sections.

Downhole Survey (DH 260)

The results of the initial downhole survey are presented on Figure 3 and on Table II below.

TABLE II
DOWNHOLE SURVEY RESULTS DH-260

Layer	Depth	V_p	V_s	u	Material
1	0-18	1,600	780	0.344	Fill
2	18-48	(2,550)	1,100	0.386	Fill
3	48-104	4,400	1,650	0.418	Alluvium
4	104-185	9,800	3,600	0.422	Wx. Rock & Rock

Typically, the shear and compressional wave velocities should change at the same depth point. The results of the original downhole survey indicate four major layers in Borehole 260. Layer 1 occurs from the ground surface to a depth of 18 feet. Velocities encountered in this layer are representative of near-surface soils (fill) with moderate density and low moisture content.

Layer 2 occurs between the depths of 18 and 48 feet. This material is representative of dense soils (fill) with moderate moisture content. The area between 35 and 55 feet exhibits erratic values of compression (p) and some erratic shear (s) values between the depths of 25 and 35 feet. It is unknown what conditions could cause these erratic arrivals. However, repeat surveys indicate that the data is repeatable. The early p arrivals may be due to a perched, saturated zone which would not significantly affect the shear wave velocity.

Layer 3 occurs between the depths of 48 and 104 feet. This layer exhibits fairly uniform p and s velocities and appears to correlate with the alluvium noted on the drill logs. Layer 4 is defined by a marked increase in both the compressional wave and shear wave velocities at a depth of 95 feet. This apparently is the soil/bedrock interface in Borehole 260, although the drill logs for the adjacent holes show rock to be much deeper (124 to 128 feet). The shear wave arrivals are often indistinct, and the shear wave velocity observed leads to a rather high calculated value for Poisson's ratio. These two factors, combined with the moderate compressional wave velocity (9,800), tend to indicate that the bedrock may be fractured and/or weathered.

<u>Downhole Survey (DH 261A)</u>

The results of the second downhole survey performed in DH 261A are presented on Figure 4, and in the following table:

TABLE III

DOWNHOLE SURVEY RESULTS DH 261A

Layer	Depth	V_p	V_s	u	Material
1	0-10	1,820	840	0.365	Fill
2	10-34	2,200	1,250	0.262	Basalt Rubble
3	34-60	5,000	2,200	0.380	Same,Saturated
4	60-132	8,400	2,650	0.445	Basalt Flow
5	132-212	5,650	1,600	0.456	Sediments
6	212-250	10,400	2,480	0.470	Sediments

The results of the downhole survey indicate six layers of differing compressional and shear wave velocity. Layer 1 occurs between the ground surface and a depth of 10 feet. Velocities encountered in this layer are representative of near-surface soils (fill) with moderate density and low moisture content.

Layer 2 occurs between depths of 10 and 34 feet. The velocities encountered in this layer are representative of the unsaturated basalt rubble noted on the drill hole log. Layer 3 occurs between depths of 34 and 60 feet. The velocities encountered are representative of saturated materials. The water table in DH 261A was encountered at a depth of 33 feet during drilling. The materials between depths of 33 and 53 feet were logged as basalt rubble, with a gravel bed between 38 and 40 feet.

Layer 4 occurs between the depths of 60 and 132 feet. The higher compressional and shear wave velocities in this layer are representative of fairly dense material. The material between 53 and 122 feet was logged as a basalt flow with interbedded layers of clay and a breccia zone between 98 and 104 feet. Layer 5 occurs between depths of 132 and 212 feet. This material corresponds to the tuffaceous sediments noted on the drill hole log between 122 and 252 feet. Both

the compressional and shear wave velocities show a decrease in this layer, indicating fairly dense materials, but not as dense as the overlying basalt flow.

Layer 6 occurs between depths of 212 and 250 feet. The velocities in this layer show a marked increase from those of Layer 5, although the drill hole log still indicates the material to be tuffaceous sediments. In the event that the materials between 212 and 250 feet are tuffaceous sediments, they are very dense.

Cross-Hole Survey

The cross-hole survey results correlate reasonably well with the downhole survey results from DH-260. The cross-hole data shows more detail at each depth, but the overall layering is less defined. The results are presented on Figures 7 through 10 and on Table IV below. No data was obtained at a depth of 25 feet because the downhole hammer would not function properly at that depth.

TABLE IV

CROSS-HOLE SURVEY RESULTS

(AVERAGE VALUES)

Layer	Depth	V_p	V_s	u	Material
1	0-17	1,500	800	0.301	Fill
2	17-52	2,000	1,000	0.333	Fill
3	52-96	4,400	2,000	0.370	Alluvium
4	96-135	9,000	4,600	0.323	Wx. Rock
	(123-135)	12,500	5,500	0.380	Rock

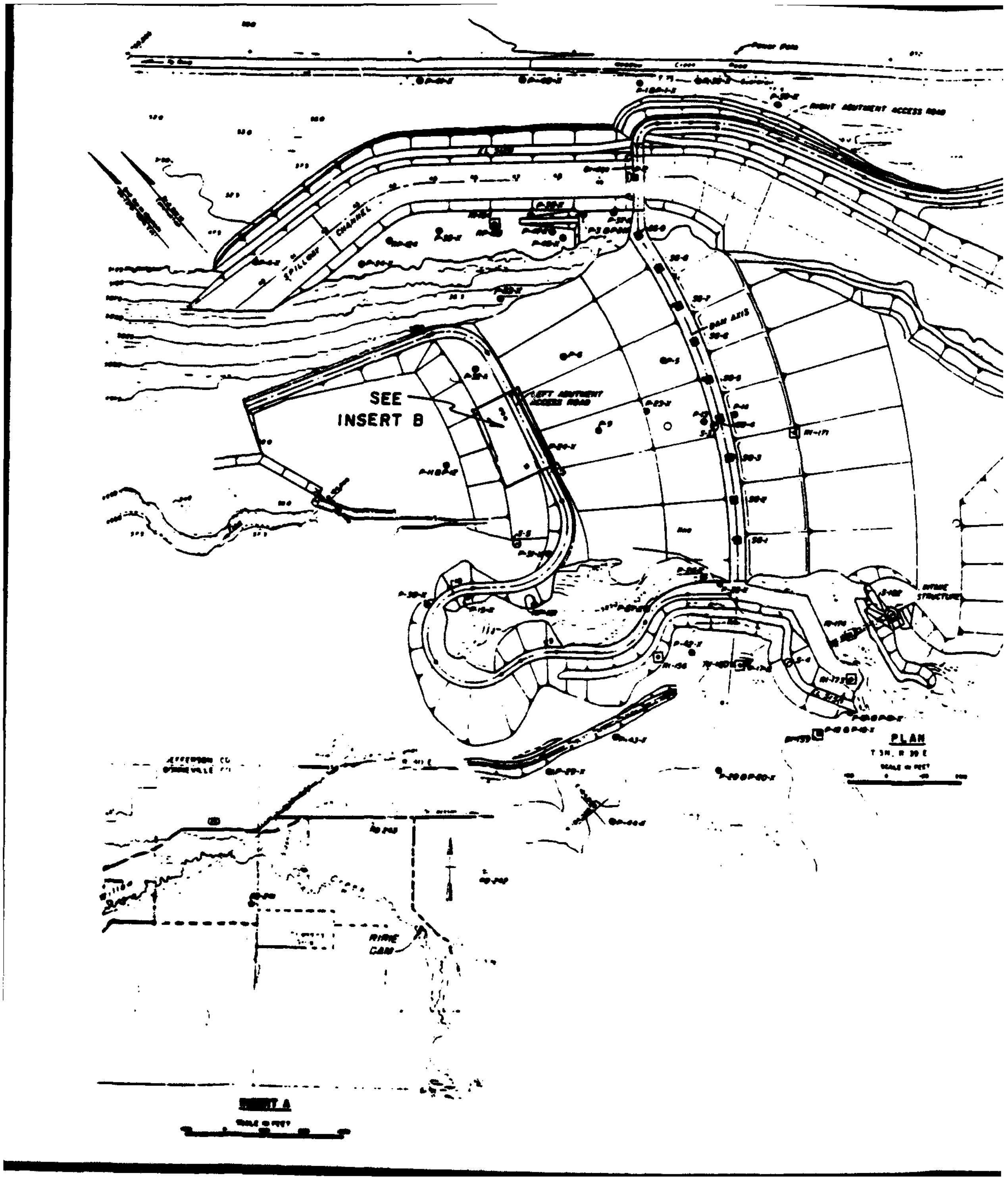
In general, it appears that there are four major layers. Layer 1 occurs between 0 and 17 feet and has relatively low shear and compressional wave velocities. This layer probably consists of moderately dense fill material. Layer 2 occurs between 17 and 52 feet and exhibits slightly higher velocities than Layer 1. This layer probably consists

of somewhat denser fill material.

The third layer ranges from 52 to 96 feet and exhibits gradually increasing velocities. The shear wave velocities increase from about 1,300 fps to about 3,000 fps and the compressional wave velocities increase from about 2,450 fps to about 7,200 fps. This layer probably represents moderately to very dense alluvium. It appears that the material is unsaturated to a depth of about 80 feet. This is in contrast with the water level of 44 feet reported in the drill log of Hole 259 provided to Davenport/Hadley (referred to as Borehole 261 on Figure 1).

The fourth layer occurs from 96 to 135 feet (total depth of the survey) and has a shear wave velocity on the order of 4,600 fps and a compressional wave velocity on the order of 9,000 fps. These velocities are much too high for fill or alluvial materials as logged in the drill logs. This layer correlates well with the downhole survey data, and probably represents weathered and/or fractured basalt bedrock. A distinct frequency change was also noted at a depth of 95 feet (see Figures 5 and 6). At a depth of about 125 feet, both the shear and compressional wave velocities increase to about 5,500 fps and 12,500+ fps respectively. This velocity increase suggests better rock quality below this depth.

LIST OF ILLUSTRATIONS


RIGHT ABUTMENT ACCESS ROAD
SPILLWAY CHANNEL
DAM AXIS
SEE
INSERT B
LEFT ABUTMENT
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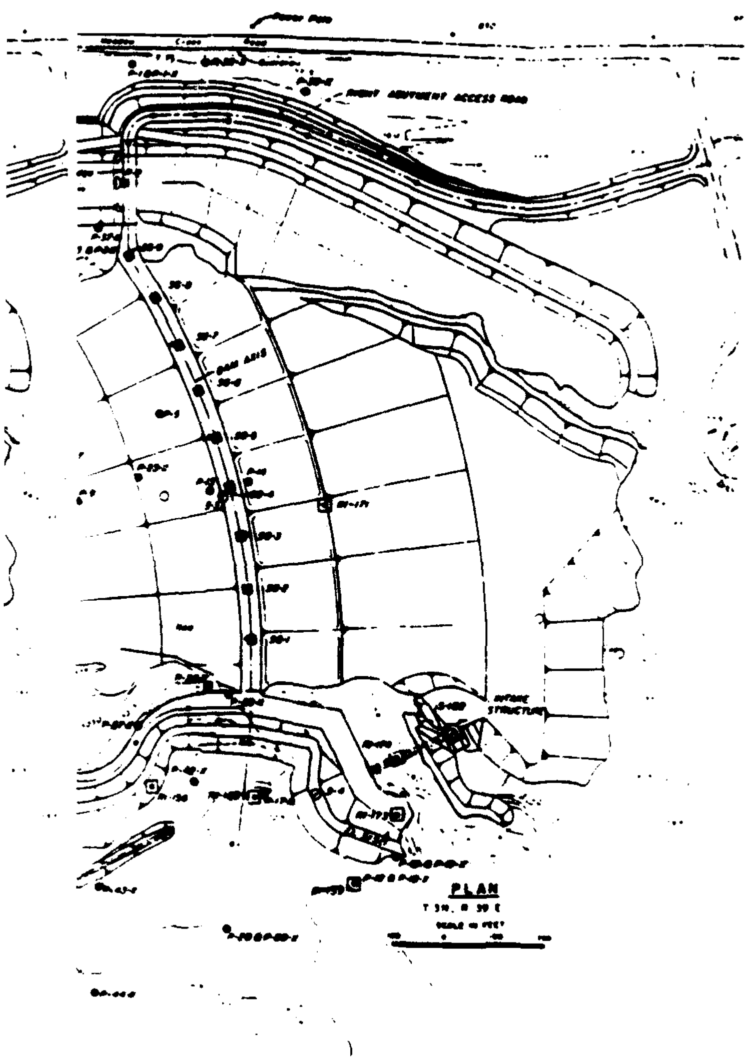
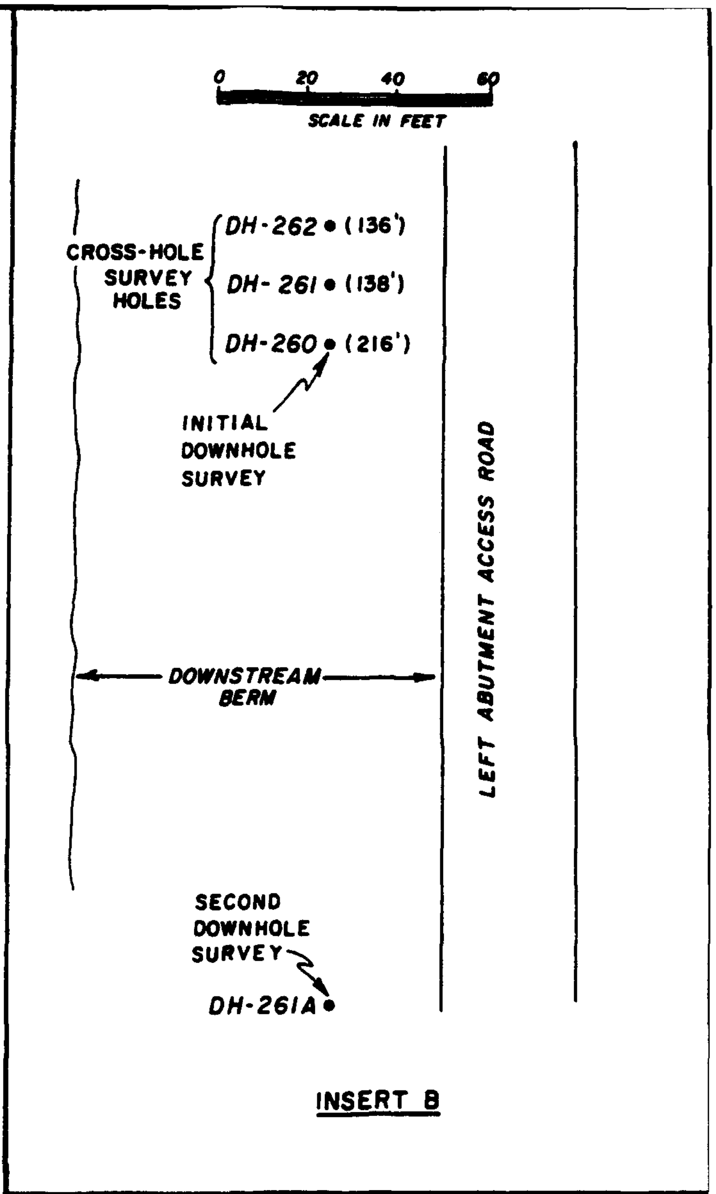
STRUCTURE
PLAN
RIRIE
DAM
INSERT A





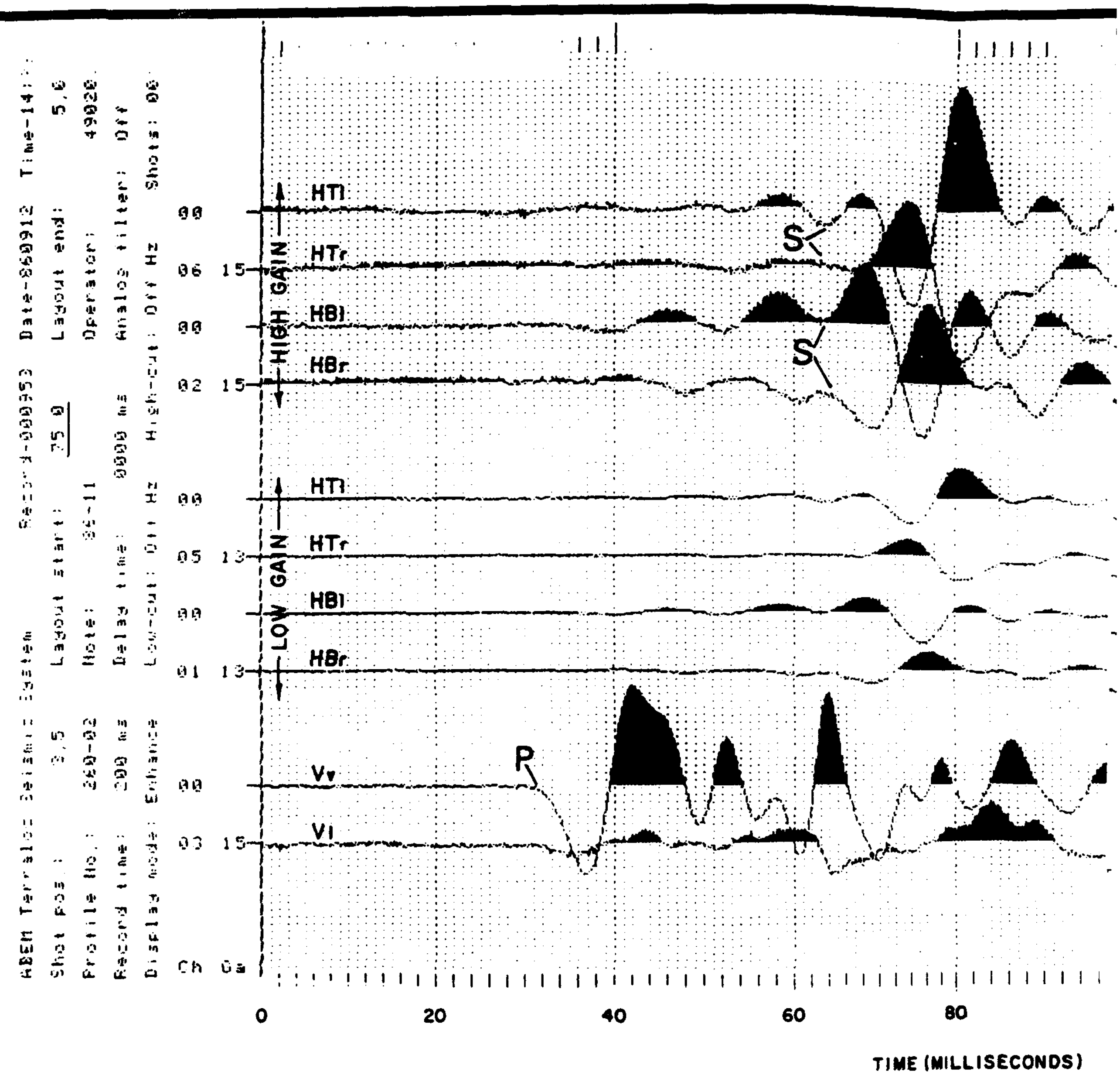
RIRIE DAM

LOCATION MAP

davenport / hadley

January 1987

FIGURE 1



HT TOP HORIZONTAL ELEMENT

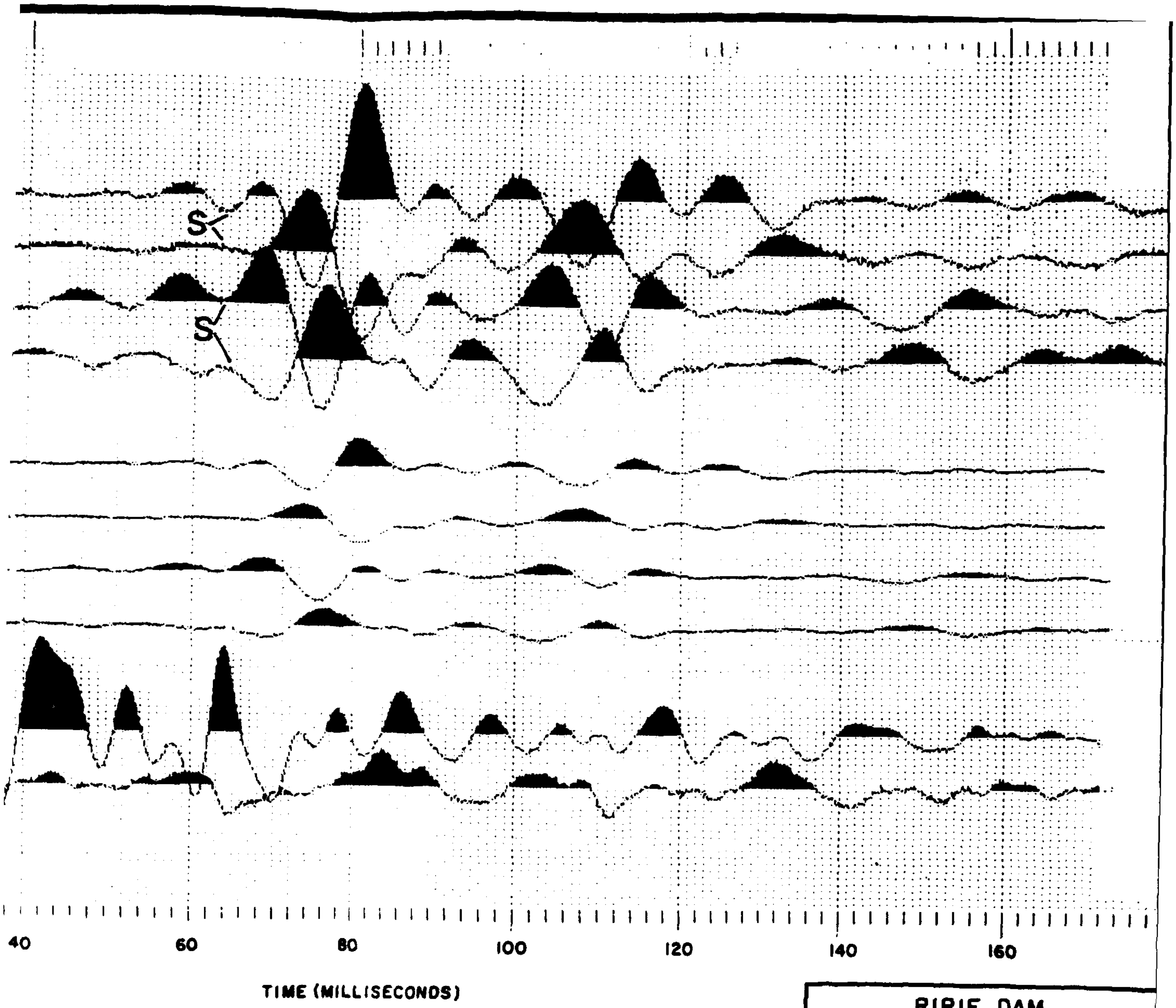
HB BOTTOM HORIZONTAL ELEMENT
(MOUNTED AT RIGHT ANGLE TO TOP ELEMENT)

V VERTICAL ELEMENT

COMPRESSIONAL WAVE A

SHEAR WAVE ARRIVAL

l - record from left hammer blow r - record from right hammer blow v - record from vertical hammer



COMPRESSIONAL WAVE ARRIVAL

NT)

SHEAR WAVE ARRIVAL

ht hammer blow v - record from vertical hammer blow

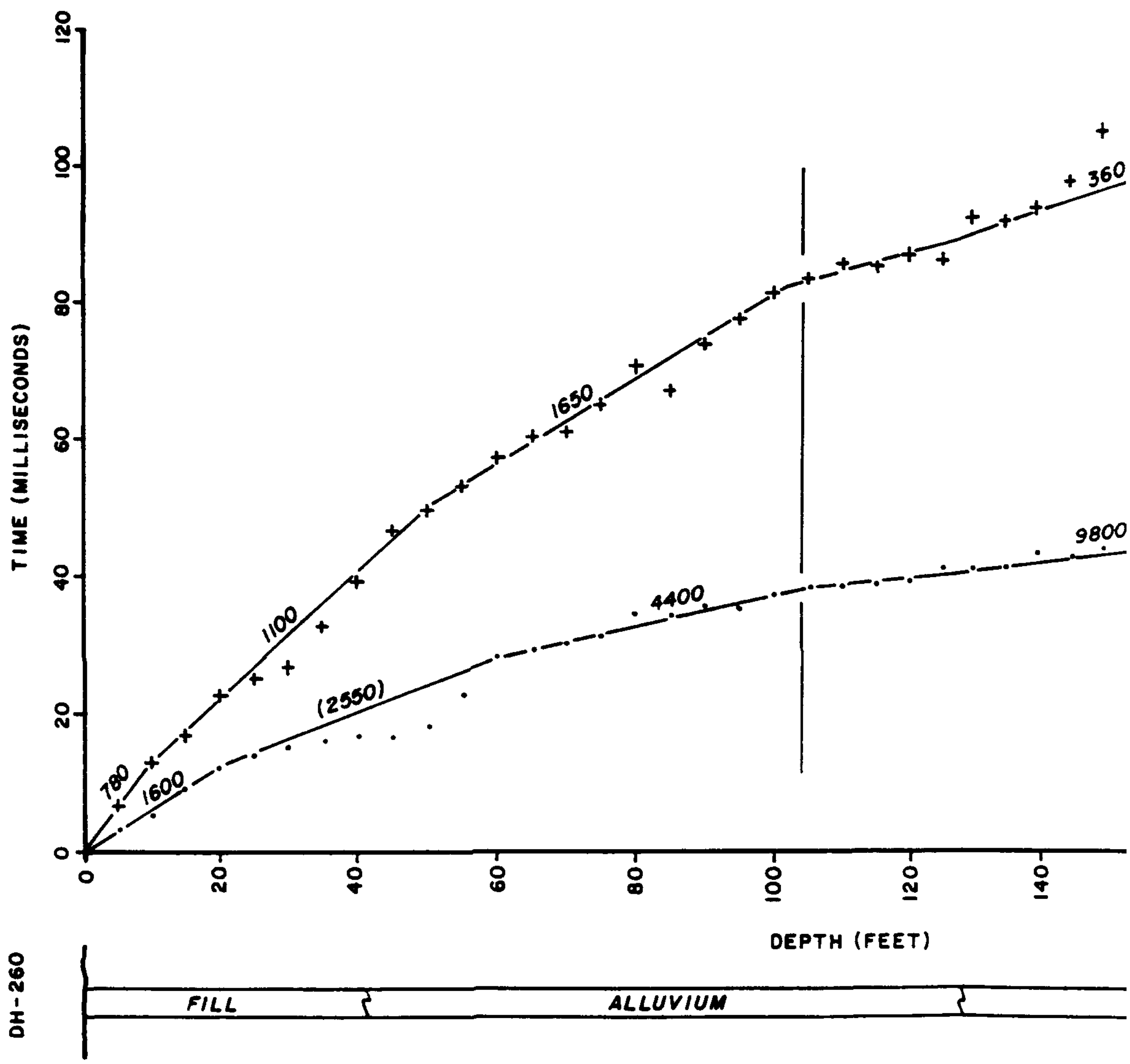
RIRIE DAM

EXAMPLE OF DOWNHOLE SEISMIC RECORD

davenport/hadley

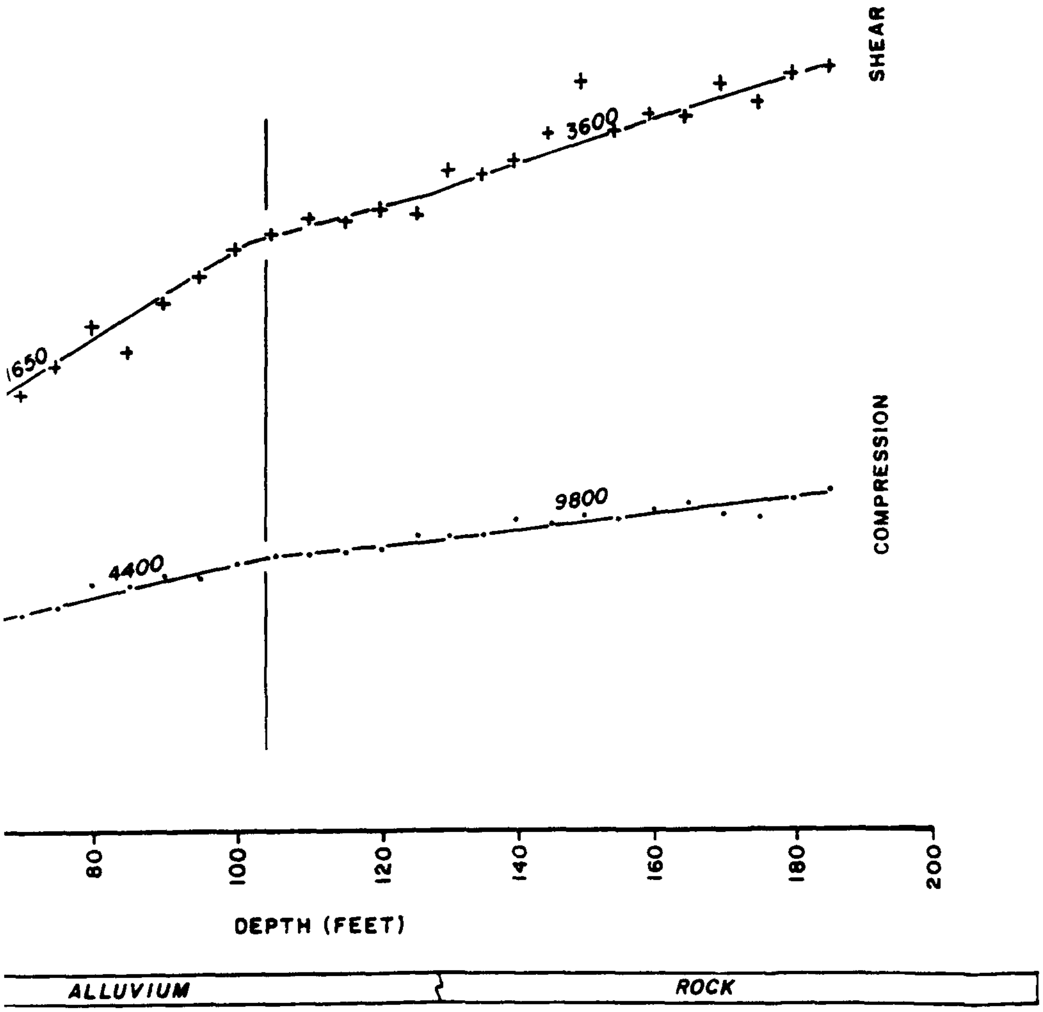
January 1987

FIGURE 2



· COMPRESSIONAL WAVE ARRIVAL + SHEAR WAVE ARRIVAL

VELOCITIES - FEET PER SECOND



+ SHEAR WAVE ARRIVAL

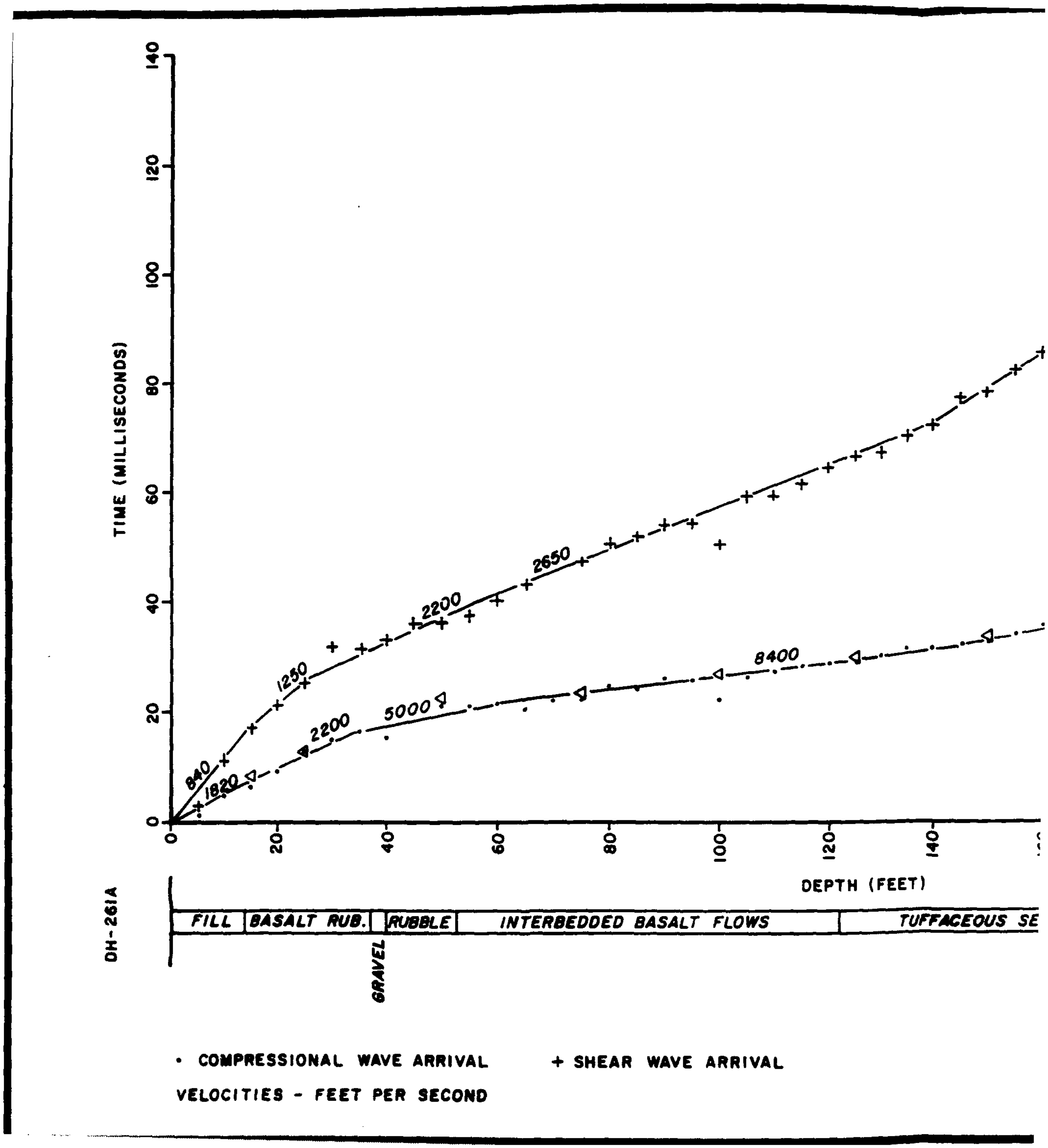
RIRIE DAM

RESULTS OF DOWNHOLE SEISMIC SURVEY DH-260

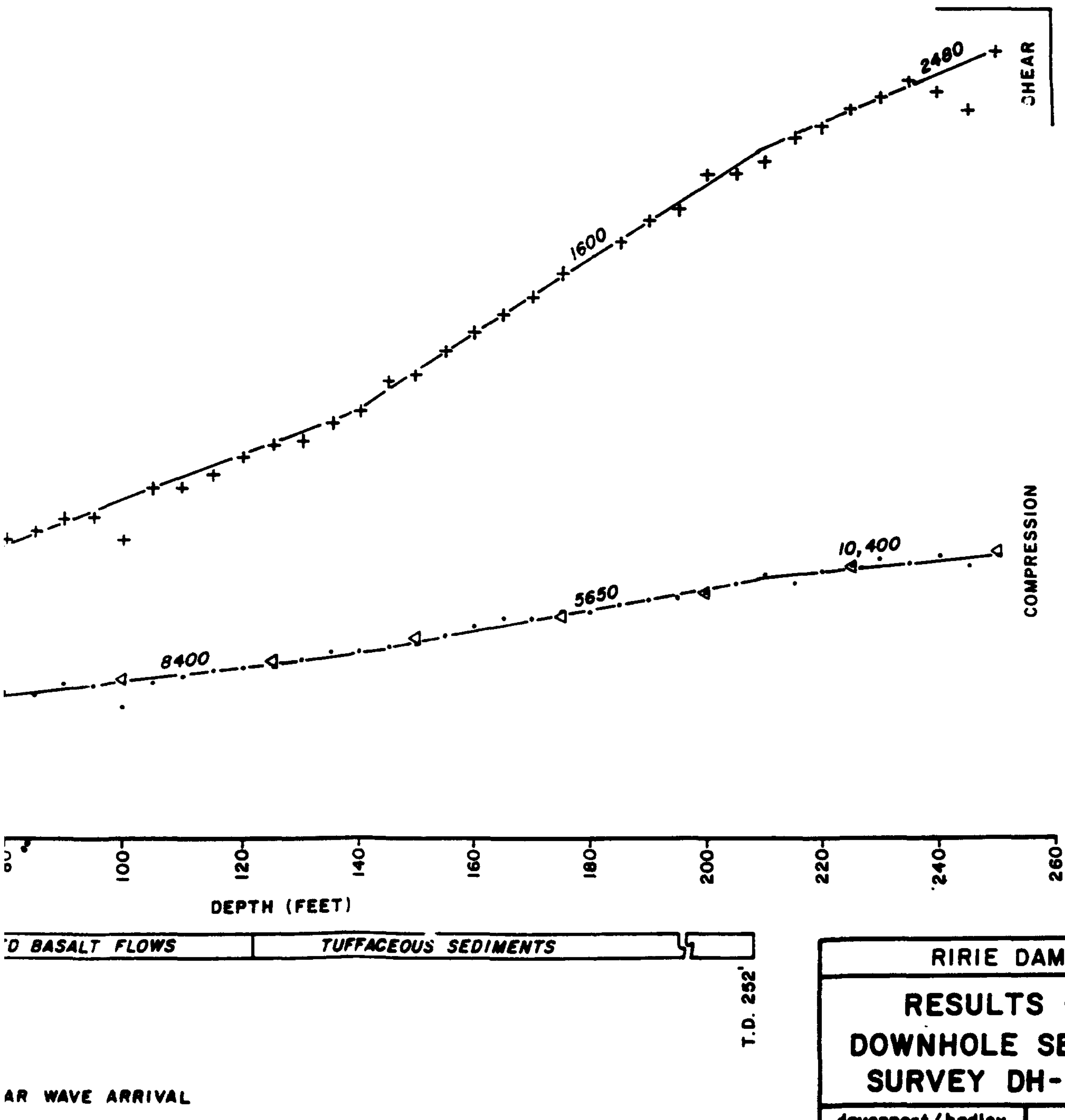
davenport / hadley

January 1987

FIGURE 3



TIME (MILLISECONDS)
0
20
40
60
80
100
120
140
DEPTH (FEET)
840
1820
1250
2200
2200
2650
5000
8400
DH-261A
FILL
BASALT RUB.
GRAVEL
RUBBLE
INTERBEDDED BASALT FLOWS
TUFFACEOUS SE
• COMPRESSIONAL WAVE ARRIVAL
+ SHEAR WAVE ARRIVAL
VELOCITIES - FEET PER SECOND



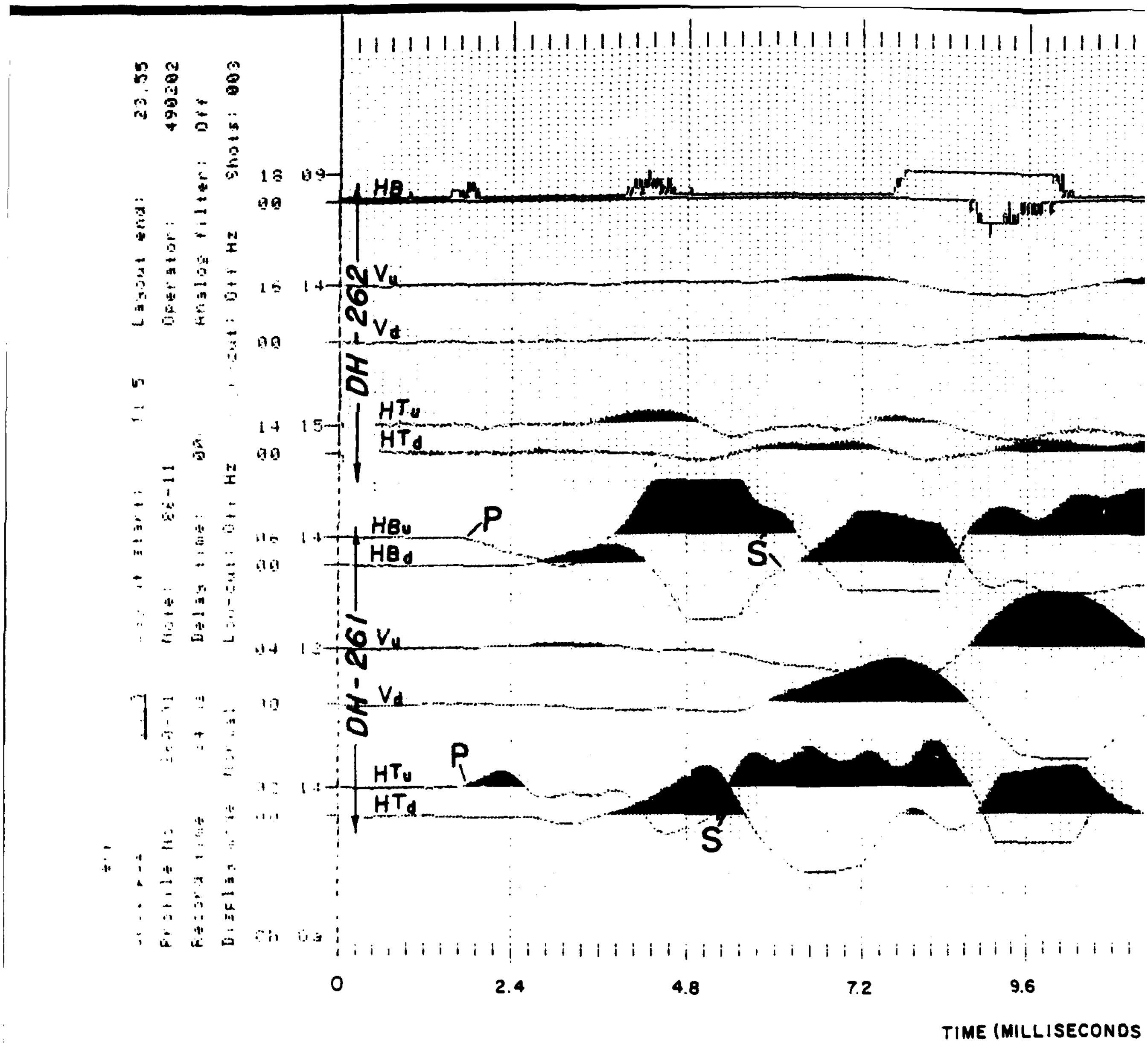
RIRIE DAM

RESULTS OF DOWNHOLE SEISMIC SURVEY DH-261A

davenport / hadley

January 1987

FIGURE 4



HB BOTTOM HORIZONTAL ELEMENT

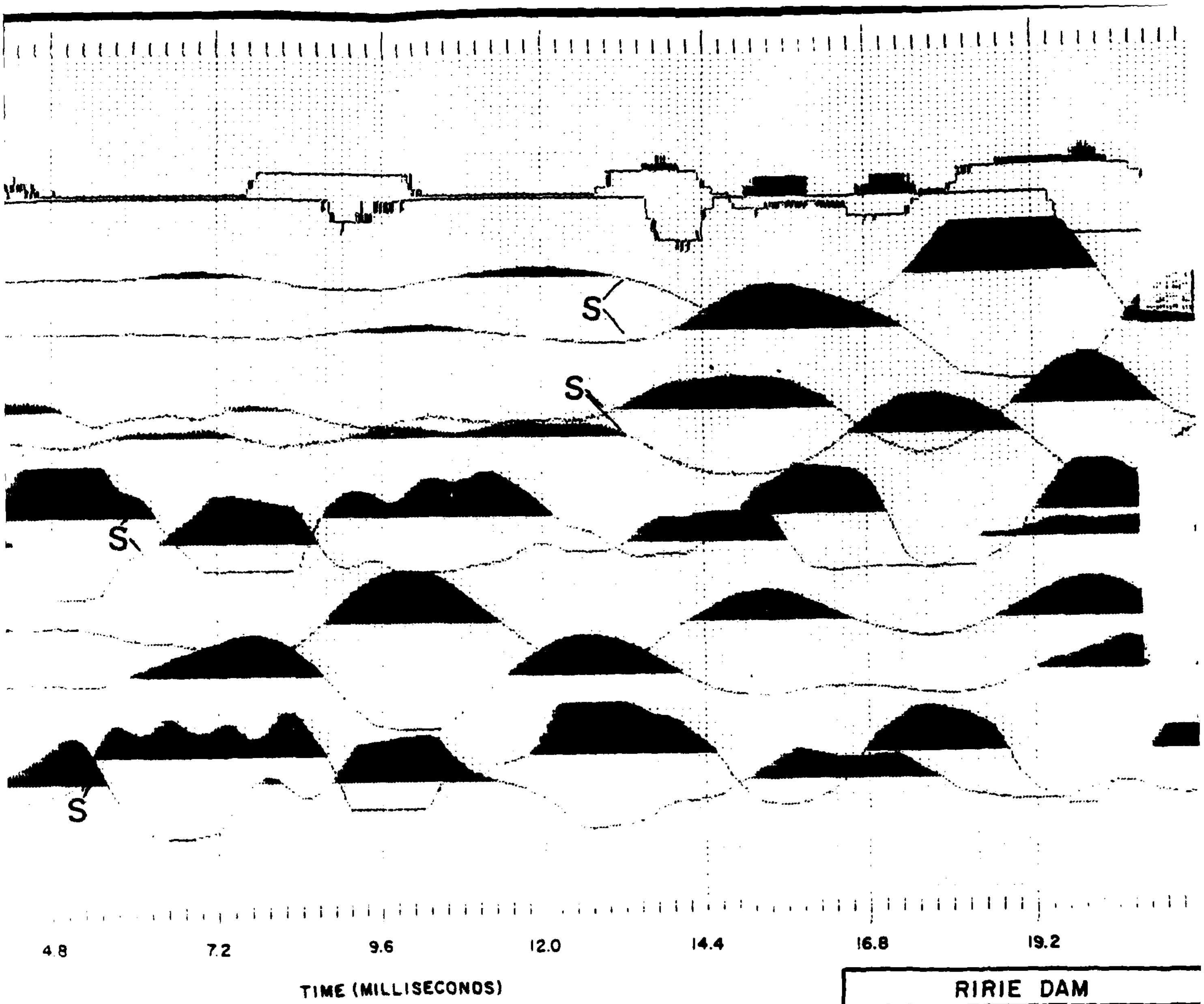
V VERTICAL ELEMENT

HT TOP HORIZONTAL ELEMENT
(MOUNTED AT RIGHT ANGLE TO BOTTOM ELEMENT)

P COMPRESSIONAL WAVE AR

S SHEAR WAVE ARRIVAL

u - record from upward hammer blow d - record from downward hammer blow



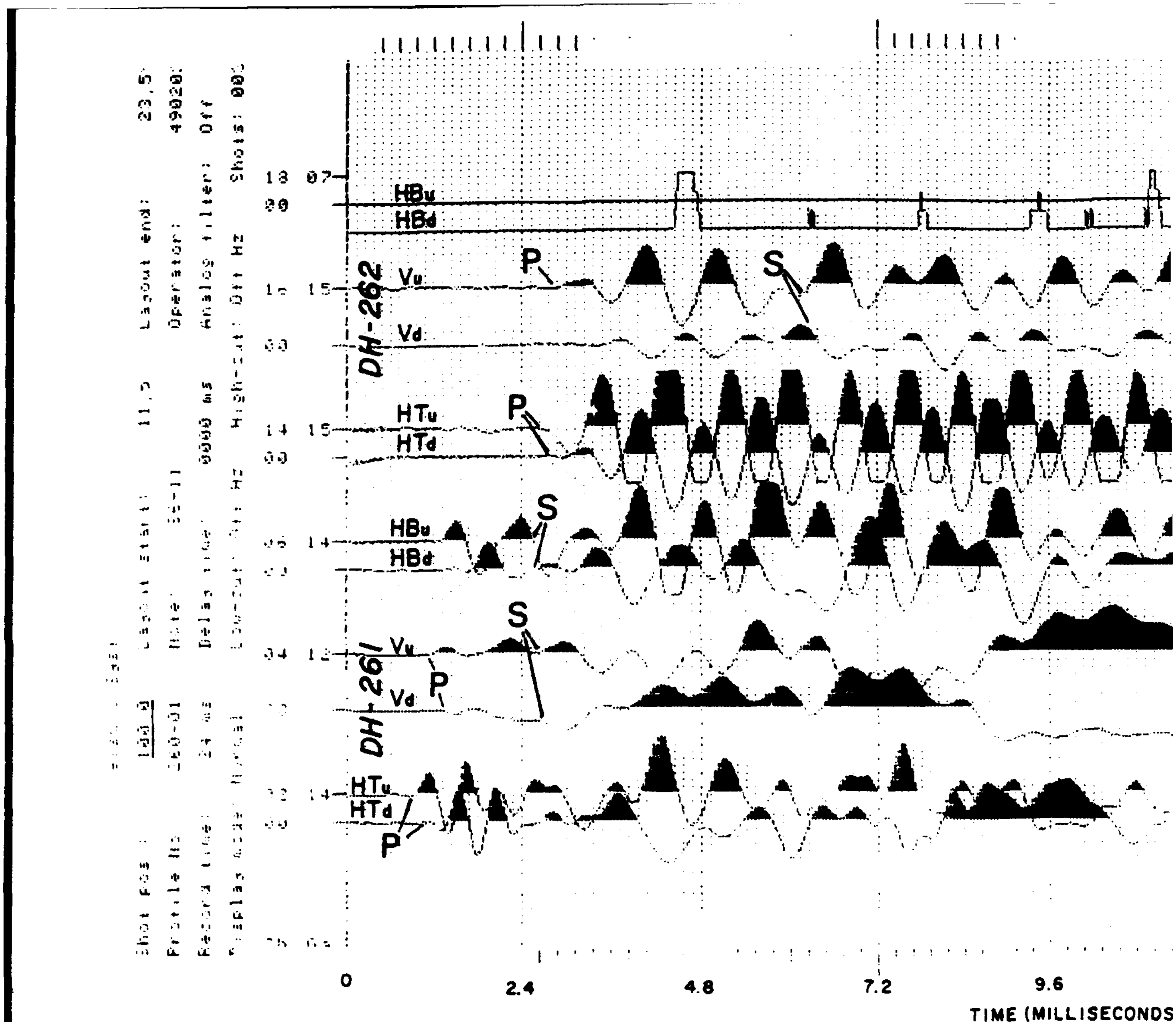
P COMPRESSIONAL WAVE ARRIVAL

S SHEAR WAVE ARRIVAL

I ELEMENT)

from downward hammer blow

RIRIE DAM	
EXAMPLE OF CROSS-HOLE SEISMIC RECORD (SOIL)	
davenport / hadley January 1987	FIGURE 5



HB BOTTOM HORIZONTAL ELEMENT

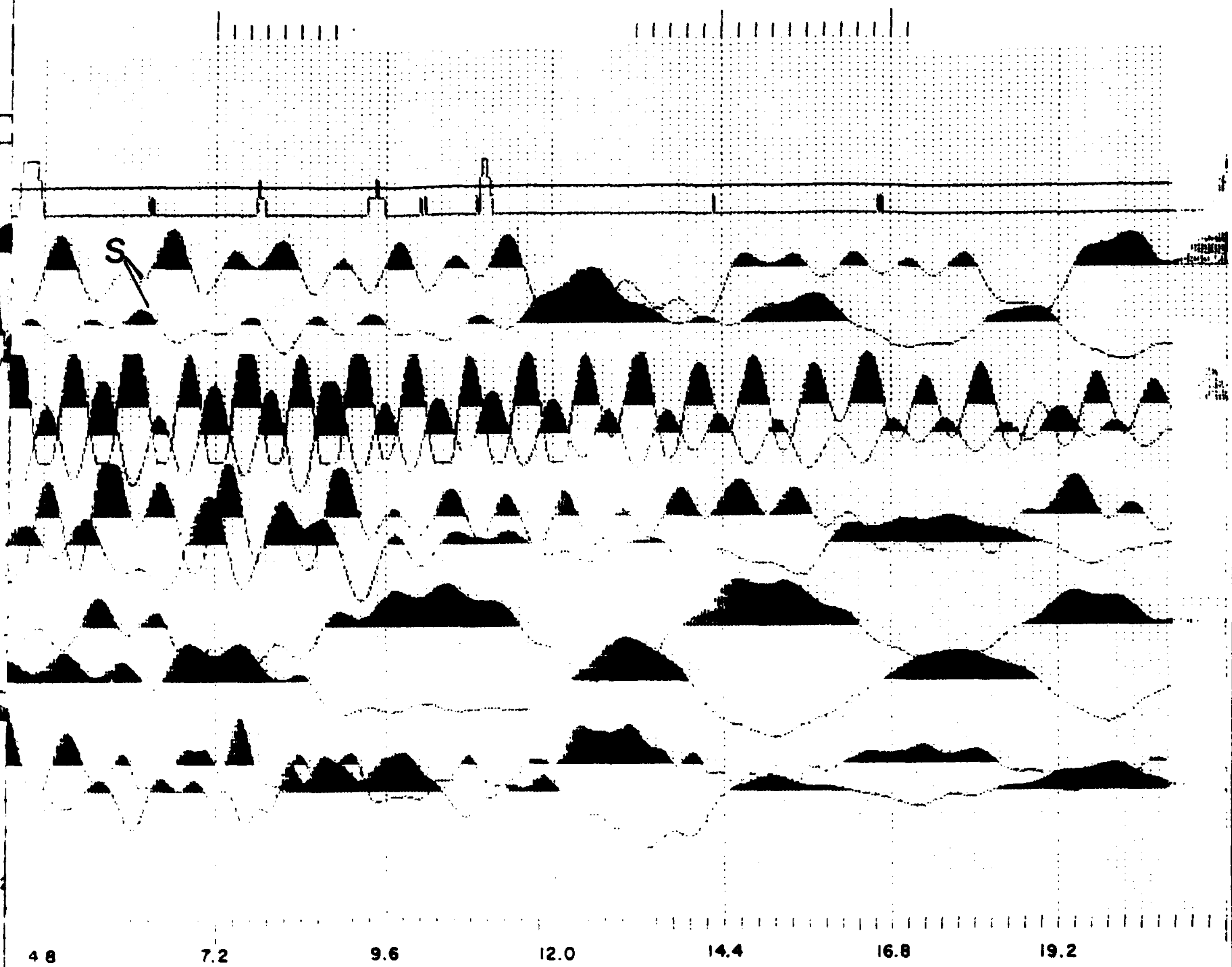
V VERTICAL ELEMENT

HT TOP HORIZONTAL ELEMENT
(MOUNTED AT RIGHT ANGLE TO BOTTOM ELEMENT)

P COMPRESSIONAL WAVE ARR

S SHEAR WAVE ARRIVAL

u - record from upward hammer blow d - record from downward hammer blow



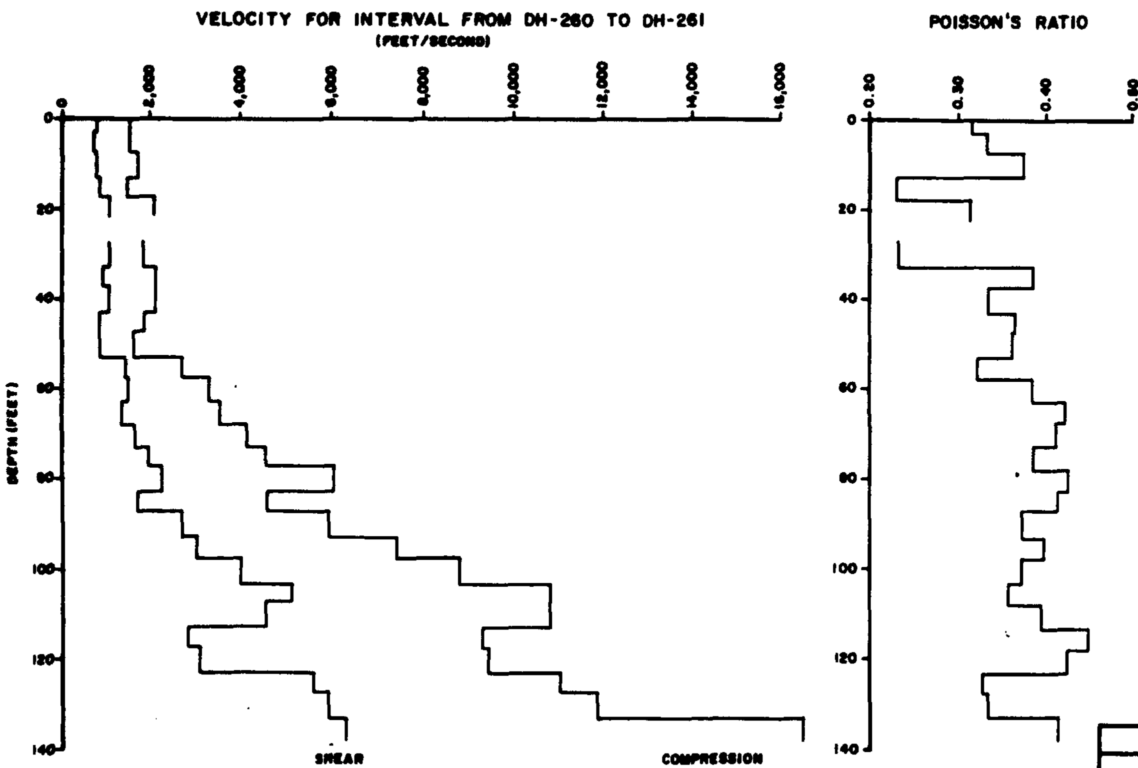
P COMPRESSIONAL WAVE ARRIVAL

S SHEAR WAVE ARRIVAL

ELEMENT)

rom downward hammer blow

RIRIE DAM	
EXAMPLE OF CROSS-HOLE SEISMIC RECORD (ROCK)	
davenport / hadley	FIGURE 6
January 1987	



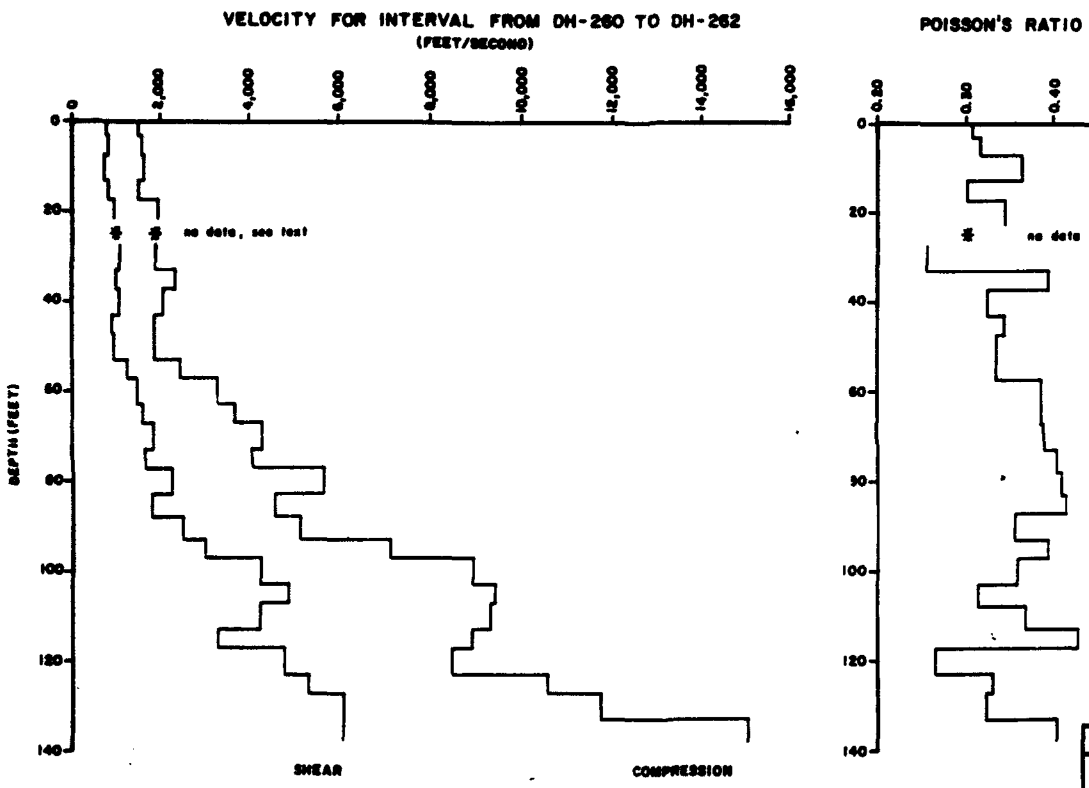
RIRIE DAM

RESULTS OF CROSS-HOLE SURVEY DH-260 TO DH-261

davenport/hadley

January 1967

FIGURE 7

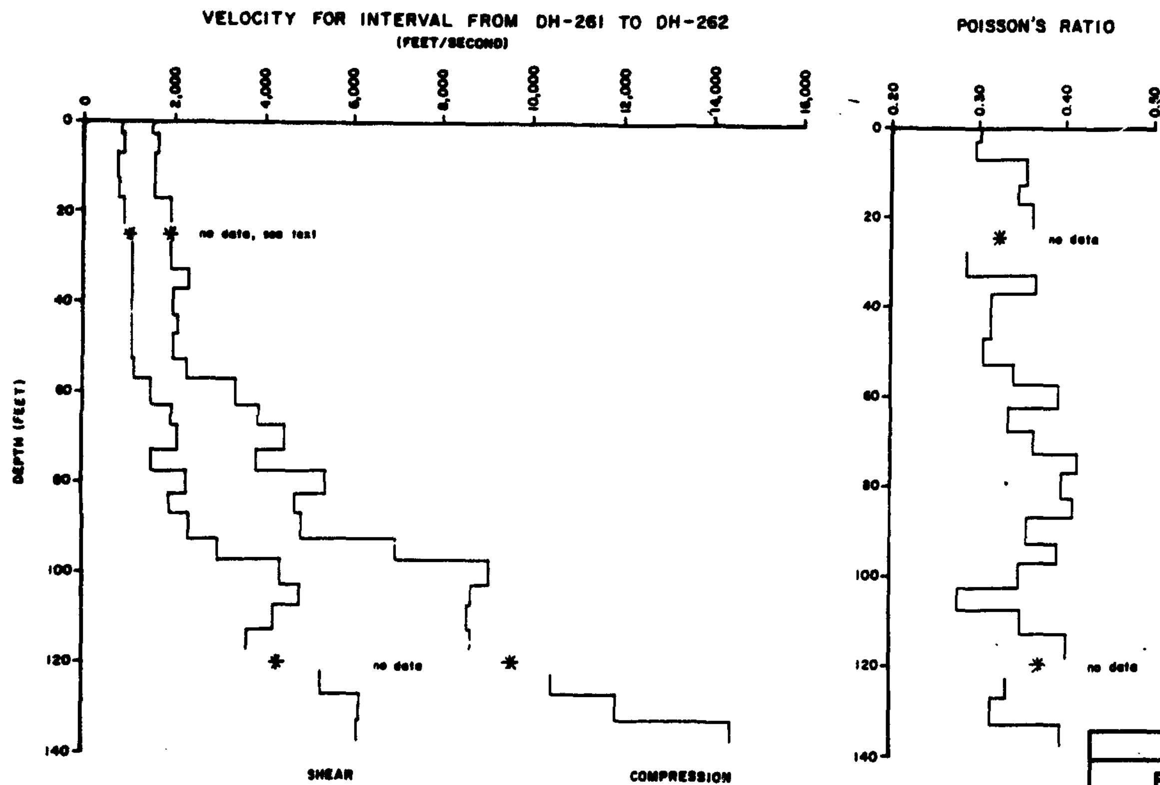


RIRIE DAM

RESULTS OF CROSS-HOLE SURVEY DH-260 TO DH-262

davenport/hadley
January 1987

FIGURE 8



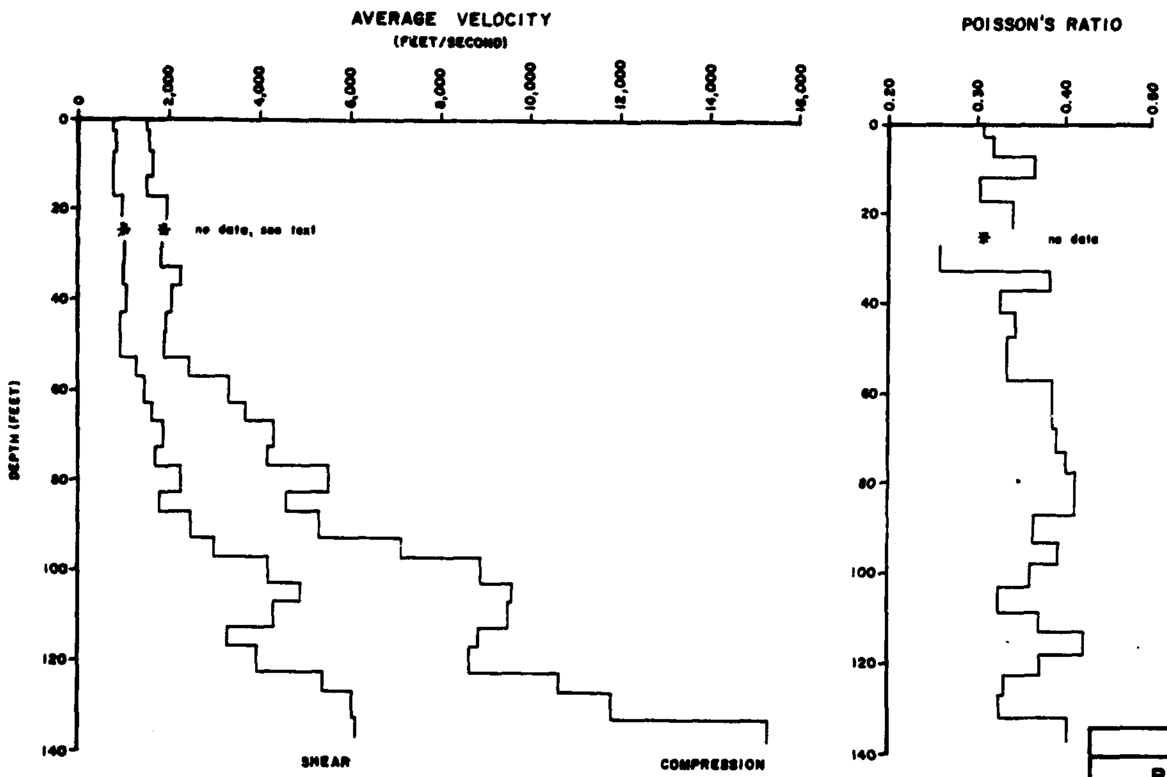
RIRIE DAM

RESULTS OF CROSS-HOLE SURVEY DH-261 TO DH-262

davenport/hadley

January 1987

FIGURE 9



RIRIE DAM

RESULTS OF CROSS-HOLE SURVEY AVERAGE VALUES

davenport/hadley

January 1987

FIGURE 10